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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARD

(ACRS)

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SUBCOMMITTEE ON MATERIALS, METALLURGY AND

REACTOR FUELS

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WEDNESDAY

SEPTEMBER 23, 2009

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ROCKVILLE, MARYLAND

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The Subcommittee convened in the Commissioners' Hearing Room at the Nuclear Regulatory Commission, One White Flint North, 11555 Rockville Pike, at 8:30 a.m., Dr. William J. Shack, Chairman, presiding.

SUBCOMMITTEE MEMBERS PRESENT:

WILLIAM J. SHACK, Chair

SAID ABDEL-KHALIK

J. SAM ARMIJO

SANJOY BANERJEE

MARIO V. BONACA

OTTO L. MAYNARD

JOHN D. SIEBER

CONSULTANT TO THE SUBCOMMITTEE PRESENT:

GERY WILKOWSKI

NRC STAFF PRESENT:

BRIAN HOLIAN

LOUISE LUND

ALLEN HISER

KAMAL MANOLY

HANS ASHAR

MICHAEL MODES

ALSO PRESENT:

MIKE GALLAGHER
JOHN O'ROURKE
STAN TANG
FRANCIS KU
PETE TAMBURRO
CLARENCE MILLER
MARCOS HERRERA
RICHARD WEBSTER
PAUL GUNTER

T-A-B-L-E O-F C-O-N-T-E-N-T-S

T-A-B-L-E O-F C-O-N-T-E-N-T-S

P-R-O-C-E-E-D-I-N-G-S

8:29 a.m.

CHAIRMAN SHACK: The meeting will now come to order.

This is a meeting of the Material, Metallurgy and Reactor Fuel Subcommittee to review the #D finite element analysis of the Oyster Creek drywell shell.

I am Bill Shack, acting chairman of the subcommittee.

ACRS members in attendance are Sam Armijo, Mario Bonaca, Otto Maynard, Jack Sieber and Said Abdel-Khalik.

We also have a consultant with us, Dr. Gery Wilkowski of Engineering Mechanics Corporation of Columbus, perhaps better known as EMC2. Dr. Wilkowski has many years of experience with finite element analyses.

The members also have a report from our other consultant, Professor John Hutchinson of Harvard who can't be here today because he is in Saudi Arabia attending the inauguration of his former student Fong Shih as the founding president of the King Abdually University of Science and Technology. Many of the mechanics types in the room will remember Fong Shih for his work on the "EPRI Fracture Mechanics Handbook" and a slew of asymptotic solutions for crack tip stresses. Professor Hutchinson is well known for his work on the buckling of shelves and the sensitivity of shell buckling loads to imperfection. We asked him specifically to review the capacity reduction factors used in the analyses performed by the licensee.

Peter Wen is the designated federal official the meeting.

Sanjoy Banerjee has arrived, another ACRS member.

The purpose of this meeting is to review Exelon's 3-D drywell shell analysis for the Oyster Creek Nuclear Generating Station and associated documents. We will hear presentations from representatives of the Office of Nuclear Reactor Regulation and the licensee, Exelon Generation Company. The subcommittee will gather information, analyze relevant issues and facts and formulate proposed positions and action as appropriate for deliberation by the full committee.

The rules for participation in today's meeting were announced as part of the notice of this meeting previously published in the Federal Register on August 26th, 2009.

We have a received a request from Paul Gunter and Richard Webster to make oral statements regarding today's meeting. We will grant them about 15 minutes at the end of the meeting to make their statements.

We also have several people on phone bridge lines, including representatives from the State of New Jersey and staff from Region I listening to the discussion. Therefore, we request the participants in this meeting use the microphones located throughout the meeting room, identify themselves and speak with sufficient clarity and volume that they may be readily heard. To preclude interruption of the meeting, the phone line is placed in a listen-in mode.

A transcript of the meeting is being kept and will be made available as stated in the Federal Register notice.

Please note that the Commission will need this room from 11:00 to 11:30 for a short public meeting and affirmation session. We will have an early lunch break from 11:00 to 12:30 and no morning coffee break, so you'll have to play that one by ear, and reconvene the subcommittee meeting at 12:30.

We will now proceed with the meeting and I call upon Mr. Brian Holian of the NRR to introduce the presenters.

MR. HOLIAN: Good morning, Chairman and ACRS members. My name is Brian Holian. I'm the director of the Division of License Renewal, and I just have a few opening comments. And I'll wait on further NRC staff introductions until after the morning, since we have an extensive presentation by the licensee this morning.

As you mentioned, the purpose of today's meeting is to review the Oyster Creek drywell shell analysis. This analysis and issue has a long history; it started with corrosion back in the late 1980 time frame. And during license renewal review in particular, and as appropriate, you know, we shed a spot light on their review and their analysis and that's part of the reason why we're here today.

Many organizations and individuals, you know, have expressed interest and spent significant resources reviewing this issue. The licensee, their consultants, the staff, their consultants, several public interest groups, the State of New Jersey, a separate look at the analysis, elected officials have expressed a keen interest in this issue, and additional folks. NRC staff reviewers from technical headquarters divisions and the Division of License Renewal reviewed this in depth during the license renewal decision process.

Additionally, as you mentioned, Region I is listening in today, and we have a senior inspector from Region I here for the staff presentation, did extensive inspections of the drywell prior to license renewal.

Several separate analyses were performed to verify that ASME code requirements for the drywell are met. I think you'll hear details from them both from the licensee and the staff this afternoon on those analyses.

Today's agenda has the licensee presenting a majority of the morning and into the afternoon followed by the NRC staff and several members from the public.

With that, I'll wait on NRC introductions and turn it over to the licensee, Mike Gallagher, the vice-president for Exelon.

MR. GALLAGHER: Okay. Good morning. My name is Mike Gallagher and I am the vice-president of license renewal for Exelon.

And before we get into today's presentation, I would like to introduce the presenters to you. So first to my left here is John O'Rourke. John is an Exelon senior project manager in license renewal and has provided oversight for the development of the Oyster Creek 3-D drywell analysis. And John has over 36 years nuclear power plant experience, primarily in engineering.

Structural Integrity is our engineering contractor that developed the Oyster Creek 3-D drywell analysis. And Structural Integrity are experts in the field of structural analysis. So with us today we have from the Structural Integrity team we have Francis Ku to my left, Stan Tang. France and Stan will be presenters. And we have Marcos Herrera in the back here. Marcus is with us today also.

So Francis Ku to my left has over nine years experience with Structural Integrity and has extensive knowledge in solving complex structural and mechanical finite element analysis problems. Francis was the primary developer for the finite element model for Oyster Creek drywell and he'll be presenting those details today.

And then to my right is Stan Tang, and Stan was the primary reviewer of the Oyster Creek 3-D drywell analysis. And Stan has over 30 years of experience in the areas of fatigue, fracture mechanics, thermo-mechanical stress analysis, structural dynamics, finite element methods and software development. And Stan's work covers areas in the defense and the nuclear industries. Stan is also a registered professional mechanical engineer in the State of California.

And then to my far right is John Hugnagel. John is our license renewal project licensee lead.

And in the back here we have Marcos Herrera, as I mentioned. He's from Structural Integrity. Marcos was the primary approver of the Oyster Creek 3-D drywell analysis. Marcos has over 35 years experience in stress, fatigue and fracture mechanics analysis of power plant components. Marcos was recently promoted to vice-president and general manager of Structural Integrity's nuclear plant services. He's been extensively involved as both a performer and project manager in the evaluation of structural margin for BWR components. He's experienced in the ASME boiler pressure vessel code section 3 and section 11 evaluations for repair and replacement projects. And Marcos is also a registered professional engineer in the State of California.

Also we have behind me here is Dr. Clarence Miller. As many of you on the subcommittee for the Oyster Creek license renewal remember, Dr. Miller attended the full committee meeting actually and presented information for you.

Dr. Miller has an extensive career in the area of research and design related to the strength and stability of shell structures. Dr. Miller is currently an independent consultant after retiring from Chicago Bridge & Iron following 44 years of service. Dr. Miller is also a registered professional engineer in the State of Illinois. Dr. Miller has written over 90 papers, publications and test reports related to shell stability. In 1969 and offshore storage structure that Dr. Miller designed was selected as one of the ten most outstanding engineering achievements by the National Society of Professional Engineers. Dr. Miller told me that a couple of the other ones that were selected that year were the 747 and the space shuttle. So they were those kind of engineering feats.

This offshore storage tank is anchored to the bottom of the Persian Gulf in 160 feet of water. The tank is 1 300-foot diameter spherical dome roof that is subjected to actual compression in combination with internal or external pressure. And the dome has both radial and circumferential stiffeners.

So aside from those kind of achievements, Dr. Miller was also the primary author of ASME nuclear code case and N284 in 1979 and N284-1 in 1991. And that's the metal containment shell buckling design methods. So Dr. Miller will presenting today on this topic. We used code case N284 in the Oyster Creek 3-D drywell analysis.

Okay. We can go to slide 2. So slide 2 shows our agenda for the presentation. And the presentation will provide an overview of the information from the reports we submitted to the staff on January 22nd, 2009. Where appropriate in the presentation, throughout the presentation we included the report page and a figure or table reference for your information. And with our experts here today, we should be able to get into any level detail that we need to answer your questions.

So, slide 3. I'd just like to go into a little background first, since it's been awhile since we met with you all on this topic. So on January 18th, 2007, we met with the ACRS subcommittee for the Oyster Creek license renewal review and we gave a very detailed presentation of the drywell corrosion issue. And if you recall, we went through, you know, many aspects of that, including, you know, how the issue was identified in the 1980s, how it was corrected in 1992 with the removal of the sand and the sandbed, removal of the corrosion and the application of the three-part epoxy coating system on the sandbed. And then our ongoing monitoring program, the major items which are what we do now is every four years, every other refueling outage, we go into the sandbed and we do 100 percent visual inspections of the coating. And also every other outage we repeat all our UT measurements that we've taken to verify that in fact the corrosion is not ongoing in the drywell. And so we continue that activity. And we went through all those details in this meeting on January 18th, 2007.

But one of the items we presented was the licensing basis GE analysis on drywell thickness that we used as our acceptance criteria for our ongoing UT measurements that are taken at sandbeds every refueling outage. And we showed the calculated thickness margins and why these calculated thickness margins are conservative. And then on February 1st, 2007 we met with the ACRS full committee for the Oyster Creek license renewal and we presented some information as a follow up to the subcommittee meeting. Two of those were related to our presentation on the GE analysis, on the drywell thickness, and they're as follows: One was whether it was appropriate to use the modified capacity reduction factor in the analysis. And so we had brought Dr. Miller and Dr. Miller presented why the use of the modified capacity reduction factor was appropriate. And he's here today to go over that information.

And another item was a comment that the subcommittee had about that, you know, we could probably better understand the thickness margins maybe better understood with a modern 3-D finite element model where various thickness and thickness configurations could be evaluated. And we agreed with the subcommittee on this point and committed to performing a 3-D finite element analysis of the

Oyster Creek drywell prior to the period of extended operation.

On February 8th, 2007, the ACRS issued their letter recommending the license renewal for Oyster Creek with some conditions. And one of the conditions was for the staff to add a license condition on our 3-D analysis commitment. And we formalized our commitment in a letter to the staff on February 15th, 2007. We embarked on the analysis right after that meeting and we completed the analysis and submitted it to the staff on January 22nd, 2009. The period of extended operation would start in April, April 9th, 2009. So it's important to note that the analysis matches our commitment.

The idea was to quantify the margin that is currently available. So it is based on a realistic but conservative thickness inputs based on the data taken. This is in contrast to a 1992 GE analysis which is a conservative uniform thickness in the sandbed region, and we discussed that. That is the current licensing basis and is used as the acceptance criteria for our UT thickness measurements. And then the NRC did grant the renewed license on April 8th, 2009.

Also, recently, on September 9th, 2009,

we sent in an updated information on this analysis. In preparing for this meeting, we had Dr. Miller, you know, review our analysis and he had identified two simplifying approximations that he recommended be changed and we will discuss the details of those simplifying approximations later in the presentation and their effects. But we had Structural Integrity quantify the effect of these simplifying approximations. And the result was actually a slight improvement in the safety factor in the sandbed region. So therefore, we do not intend to revise the analysis that we submitted on January 22nd, 2009. And today our presentation is primarily based on those analyses we sent in on January 22nd, 2009.

In your February 8th, 2007 ACRS letter you had asked for a briefing on the results when they became available, and so that's why we're here today. Okay. So that's the history and background. I hope that was helpful.

Okay. If we go to slide 4. You're not going to hear much from me; I'm going to turn it over to the experts. But I do just want to do an overview of the results. And so the next two slides I summarize the results. And we'll go into all the details that you need throughout the day.

So, this table here on slide 4 shows the buckling safety factors for the base case and two sensitivities we studied. It also shows the required ASME code safety factors of 2.0 for the refueling case and 1.67 when evaluated for Service Level C for the post-accident flooding case. And one thing we did mention in the report and I think is important to note is that for the post-accident flooding case, it's typically evaluated to a Service Level D situation, which has a required safety factor of 1.34. At Oyster Creek our licensing basis we conservatively evaluate this load combination Service Level C. So that provided some additional margin and insight.

And then on this table there are also the two sensitivity cases, 1 and 2. We have the safety factors listed for those. The sensitivity showed that for rather large changes in thickness, either bay-wide or locally, there is a relatively small change in safety factor. And we'll go into more of that in detail.

MEMBER ABDEL-KHALIK: I know you'll get into the details later, but just for reference, what are the safety factors for the original nominal thickness for these two load combinations?

MR. GALLAGHER: The original non-degraded thickness?

MEMBER ABDEL-KHALIK: Right.

MR. GALLAGHER: We -- we did not calculate that, Dr. Khalik, so we don't have that number.

MEMBER ABDEL-KHALIK: So when you say the --

MR. GALLAGHER: Yes, but you're saying before any corrosion and --

MEMBER ABDEL-KHALIK: Correct.

MR. GALLAGHER: We did not evaluate that situation.

MEMBER ABDEL-KHALIK: So when you talk about the design basis, shouldn't those numbers have been calculated?

MR. GALLAGHER: Well, the design basis would be based on what the code requirements -- and the code requirements are the code minimums, the 2.0 for the refueling and the 1.67 that we're using for the post-accident flooding case. So the original design basis would have just evaluated and verified that we were acceptable in those particular cases.

MEMBER ABDEL-KHALIK: So what were the

results of those evaluations?

MR. GALLAGHER: It was just that it was acceptable.

MEMBER ABDEL-KHALIK: That no quantitative --

MR. GALLAGHER: No, not in the original analysis. Now, if you're asking about the current licensing basis analysis, but that includes degradation.

MEMBER ABDEL-KHALIK: No, I'm asking for the result without any degradation.

MR. GALLAGHER: Yes.

MEMBER ABDEL-KHALIK: I'm trying to sort of apply some kind of sanity check on these results.

MR. GALLAGHER: No, we did not. Now, however, if you do look at -- Sandia did calculate that in their model which was presented, you know, in the subcommittee meeting and we can look those numbers up, but --

MEMBER ABDEL-KHALIK: If you have time later today, I think that would be helpful.

MR. GALLAGHER: Yes. We have the Sandia report with us, John? We can take a look at that. In that report there is a non-degradated. You know, now that's a different model, but it gives you some idea.

CHAIRMAN SHACK: That wouldn't have been your design basis model.

MR. GALLAGHER: No. No, it would not have been.

CHAIRMAN SHACK: I mean, you would have done some conservative calculation that would have been enough to show that you met the code, but you weren't really out to demonstrate the realistic --

MEMBER ABDEL-KHALIK: But I'm trying to compare apples and apples here.

MR. GALLAGHER: Right.

MEMBER ABDEL-KHALIK: And I'm trying to see what those values would be without such degradation.

MR. GALLAGHER: Well, one thing I will say, if you look at -- maybe we can flip to slide that might --

MEMBER ABDEL-KHALIK: If you're going to get to it later, I'm willing to wait.

MR. GALLAGHER: Just as a point, it might -- okay. Maybe we'll wait, because I --

MEMBER ABDEL-KHALIK: All right.

MR. GALLAGHER: We can look it up and there is some other information I can show you in here that gives you an idea.

MEMBER ABDEL-KHALIK: Good. Thank you.

MEMBER BANERJEE: Do you have a slide; you don't have to show it now, if you just tell me the number, I have them on the computer.

MR. GALLAGHER: Yes.

MEMBER BANERJEE: Where these bays are shown?

MR. GALLAGHER: Yes, let's just go to that for a minute. Slide 12. If we can go to that, John.

And again, we'll go into the detail of how we built this up. But this slide 12, if you'll look at slide 12, it is a bottom view of the containment. So you're looking at the sphere from the bottom. And the way that the bays are numbered, you can see they're odd numbers. It goes from one to nineteen. There's ten bays. And they're centered around the vent headers. The vent headers are the large downcomer pipes. So this is again a bottom view and the orientation.

MEMBER BANERJEE: So Bay 19 is where -- the 720 is a measure of the thickness, or the --

MR. GALLAGHER: Yes, we'll go into the details on that, but the Bay 19, what that shows is, you can see there's actually three areas that are annotated. The blue is 826, so that's the thickness that we assigned to that area above 11-foot elevation, but in the sandbed. Eight-hundred-twenty-six mils is what that is. And then the green is below 11-foot elevation, and that's 826 mils. And then the circle there, the rather large circle is a locally-thinned area based on some external data points, and we'll show you that. And we assigned the entire circle 720 mils. And so we showed some thinning at that point. So that's how this is all set up.

MEMBER BANERJEE: And you say the entire circle is that little circle that you've drawn there, or --

MR. GALLAGHER: Yes, it's the circle that the 720 box arrow points to. And so that's actually a 51-inch diameter circle.

MEMBER BANERJEE: Thank you.

MR. GALLAGHER: Okay. And so where we are, I mentioned the Oyster Creek licensing basis, you know, conservatively evaluates the load combination through Service Level C, and that this chart shows the sensitivities.

So if you go to slide 5, again this just reiterates our overall conclusion. We'll go into the details. For the normal operating conditions, the limiting condition is the refueling condition. And for this condition the current safety factor in the limiting sandbed bay is 3.54, which results in a safety margin greater than the ASME code specified safety factor of 2.0.

For the emergency condition, the limiting condition is the post-accident flooding case. For this condition, the current safety factor of the limiting sandbed is 2.02, which results in a safety factor margin greater than that specified Service Level C, which is 1.67.

And then our conclusion on the sensitivity studies, we demonstrate the significant thickness changes could occur or measurement of certainties could exist without a significant reduction in the margin to the ASME code specified safety factors. And again, we'll go into the details and get into any questions you may have.

Are there any questions before we start off?

Okay. So with that, let me turn it over to John O'Rourke and he'll get into the first part of the presentation, which is about the overall drywell description and then thickness measurements.

MR. O'ROURKE: Thanks Mike.

This is John O'Rourke from Exelon. And what I'd like to start off with is a brief description of the Oyster Creek drywell on slide 7.

Shown on slide 7, which is also figure 1-1 in the base case report, this is a generic drawing of a Mark 1 containment similar to the Oyster Creek drywell. And I say generic, because some of the dimensions on that are slightly different. I will tell you what the Oyster Creek dimensions are. But this shows the overall configuration for the drywell.

The modeling of the shell for 3-dimensional finite element analysis will be discussed in more detail in the presentation, but while we have the illustration, I'd like to point out the various areas of the shell that we'll be talking about during the presentation.

The drywell itself is 105-feet tall from the top of the head to the bottom of the shell and is made up of steel plates of varying thicknesses. The upper cylinder part, which is this upper cylinder here, is 33-feet in diameter. You then have a knuckle area in here, which is the transition between the cylindrical shell and the spherical shell. And then the spherical shell itself is 70 feet in diameter. And we divide that into sections we call the upper shell, the middle shell, the lower shell. And then we have the sandbed region, which is this small region right down here at the bottom of the shell. And then we have the embedded region. We call this area that's embedded in the concrete as the embedded region.

Now the Oyster Creek drywell was originally designed with this sandbed region and it was filled with sand at the time it was designed and built. And the cause of the historical corrosion in this area was water that got into the sandbed region and was held against the shell by the sand. That sand was permanently removed from this area in the early 1990s and the exterior of the drywell shell was cleaned and coated with epoxy to arrest corrosion, as Mike had previously mentioned.

MEMBER SIEBER: I have a question.

MR. O'ROURKE: Yes?

MEMBER SIEBER: The sand is in there to provide stability to the shell? That was the original design?

MR. O'ROURKE: Right.

MEMBER SIEBER: So now when you remove it, what change do you make in the stability?

MR. O'ROURKE: Well, that situation was analyzed by GE at the time before we removed the sand, and it was determined that it was acceptable from a stability standpoint for the shell without the sand.

MR. GALLAGHER: So all the analyses that were done, you know, the GE analyses we described before, included without sand and then the analysis we did --

MEMBER SIEBER: But the whole structure now is supported by a relatively thin membrane of drywell shell? Everything above it supported by that, right?

MR. O'ROURKE: And that was analyzed at the time before the sand was removed.

MR. GALLAGHER: My understanding; I don't know if you can comment further, Stan, it was a like a cushion transition. If you can go to the microphone.

MR. TANG: In our analysis we did not consider the support of the sand because it is removed. But the bottom half is embedded in the concrete. So we model those support conditions.

MEMBER SIEBER: I admit the very bottom of the shell is very stable the way it's constructed, but I would worry about removing the support. And you say there is analysis on record?

MR. GALLAGHER: Yes.

MEMBER SIEBER: What's the date of that analysis?

MR. GALLAGHER: That was from 1992 when the corrective action was put in place.

MR. O'ROURKE: And it was done prior to removing the sand.

MR. GALLAGHER: Right. Right.

MEMBER BANERJEE: But the vent structures, they don't provide any support, right, because you have an expansion bellows there? So it's primarily the concrete at the bottom and the sand that provided support? Is that correct?

MR. O'ROURKE: That is correct, yes.

MEMBER BANERJEE: And there is nothing above the vent structures? There's just a gap?

MR. O'ROURKE: There is a small three-inch gap between the shell itself and the concrete surrounding the shell.

MR. GALLAGHER: But there are support beams for the --

MEMBER BANERJEE: Well, you have trusses inside.

MR. O'ROURKE: It's supported at the top by the star truss and at the bottom by the embedded concrete.

MR. GALLAGHER: And there's a lower support beam also of the drywell.

MEMBER BONACA: The analysis contains that conditions, too? I mean, considers seismic?

MR. GALLAGHER: Yes, the original licensing basis considers all that. And, you know, what we did in this analysis, as the inputs we used all the licensing basis; and we'll go into all the details on that, but licensing basis inputs and the design drawings and that type of thing to develop the model and the licensing basis load combinations, and things like that. The only thing we changed; and John's going to go into the details on the thickness inputs, was based on our measurements, what are the thickness inputs in the drywell today to determine what the margin is today. And so that's what we'll go through.

MR. O'ROURKE: And I mentioned the sandbed region. Of course that's the area of interest, you know, that we've been discussing. But we still, even though there's no sand, we still call it the sandbed region. So throughout this whole presentation that's how I'm going to refer to it, too. And it refers to that small space. It's actually three-foot-four high and 15 inches wide. That's the space, when I say sandbed region. Okay?

MEMBER BANERJEE: Are there any conjectures as to how water got in there?

MR. O'ROURKE: That was extensively discussed.

MR. GALLAGHER: Yes, we basically went through all that in the subcommittee, but essentially what was happening was there was some leakage from the reactor cavity. It got in that gap between the shell and the concrete shield and got into the sand and, you know, wet sand in contact with the carbon-sealed shell caused the corrosion. So there's been some measures to reduce the water in-leakage and then obviously with the sand not being there anymore, it doesn't hold it up. And that whole area is epoxy coated now, which we do the visual inspections on. So that's the primary measures we took.

MR. O'ROURKE: And the other significance of the sandbed region, in that little space right there, that's also the area that we take the external point ultrasonic thickness measurement readings, which I'll be talking about in a little more detail in the presentation.

And as Mike mentioned, the sandbed is divided into ten bays numbered from one through nineteen centered around the vent tubes.

While I have this slide up, what I'll talk about here is included in the modeling is the six-and-a-half-inch diameter vent tubes that connect to the vent header in the torus. The model goes all the way down to the support points on the downcomers off the vent header. There are ten six-and-a-half-inch diameter vent pipes around the bottom of the drywell. Also inside the drywell and modeled in is the concrete floor which is support concrete up to an elevation of ten-foot-three, which is on the other side of the basemat. And the drywell itself is supported by the basemat which is a concrete pedestal.

The drywell thicknesses, I'll discuss that later, but they vary. The drywell itself is made up of plates of varying thicknesses and we'll talk about those. And it was constructed of SA-212 Grade B steel, which is the last part of slide 8.

On slide 9, the model, as I said, includes both the head connection bolts, includes the ten vent lines. We model penetrations, a total of 208 varying sizes from three to thirty-six inches. The equipment access hatch, we have a detailed knuckled representation. That's the transition between the cylindrical shell and the spherical shell. We modeled weld pads and supports as well as the star truss support. The drywell was modeled as --

MEMBER ABDEL-KHALIK: You may have mentioned this earlier, but what is the boundary condition at the end of the vent lines in the model?

MR. O'ROURKE: Well, could you go back to that? We modeled the vent lines, we modeled the vent header and we modeled the downcomers down to their structural supports in order to provide the appropriate boundary condition for the interface between the vent pipe and the shell.

MEMBER ABDEL-KHALIK: Okay. So these things are not cantilevered out, they're supported at the end?

MR. O'ROURKE: Yes.

MEMBER ABDEL-KHALIK: And there is load transmission to the torus?

MR. O'ROURKE: Right.

MEMBER ABDEL-KHALIK: And that boundary condition is included in the model?

MR. O'ROURKE: Yes, it is. Right, Stan?

MR. TANG: Yes, there is a column support under the one header that is connected to the bottom of the torus.

MR. O'ROURKE: So that becomes our anchor point for --

MEMBER ABDEL-KHALIK: Okay.

MR. O'ROURKE: Recognizing that the area of interest here was modeling the shell.

MEMBER ABDEL-KHALIK: Yes, I fully understand.

MR. O'ROURKE: But to provide the appropriate boundary conditions at the interface, we modeled it down to the structural support.

MEMBER ABDEL-KHALIK: Correct.

MEMBER BANERJEE: You will show us the details of that when you discuss the finite element analysis, right? How you put the support in?

MR. O'ROURKE: Stan, I think you can talk to that when you talk to the --

MR. TANG: Yes.

MEMBER BANERJEE: And the shell was

modeled, If I recall, as a sphere, right? Not in the shape that you've shown here.

MR. O'ROURKE: No, it was modeled as a spherical in the lower part and as a cylinder in the upper part.

MR. GALLAGHER: Yes, I think in the part of the presentation Francis --

MEMBER BANERJEE: He'll go into the details.

MR. GALLAGHER: Yes, he's going to do through all the details of the modeling.

MEMBER BANERJEE: Yes, right. We'll wait.

MR. GALLAGHER: It's quite extensive how the model was built, yes.

CHAIRMAN SHACK: I think you have a fair amount of detail in the model.

MR. GALLAGHER: Right.

MR. O'ROURKE: And in fact, this slide just kind of summarizes. We modeled the drywell as a non-symmetric structure, three-dimensional model using the ANSYS software. There are approximately 406,000 elements and 400,000 nodes included in the model, which we believe is realistic while maintaining some conservatism.

MEMBER BANERJEE: What was the size of these nodes, just physically, the smallest node?

MR. O'ROURKE: We have a slide that talks about the mesh sizes a little later in the presentation.

MR. GALLAGHER: So it's mesh size. Node size is just a point, isn't it, Francis?

MR. O'ROURKE: He means mesh size.

MEMBER BANERJEE: But, why don't we just wait then? If you have all the details, then we --

MR. GALLAGHER: I mean, just to, if we could just for a second --

MEMBER BANERJEE: I glanced through them, but I didn't get, you know, a physical idea of --

MR. GALLAGHER: Yes, just for a second --

MEMBER BANERJEE: -- what this actually meant in terms of nodalization or mesh.

MR. GALLAGHER: If we could just go to slide 46, and Francis is going to go through all this, but this summarizes the mesh sizes throughout the containment. And we can see the areas that we had more interest in. We had the smaller mesh sizes.

MEMBER BANERJEE: And what was the size of these corrosion areas?

MR. GALLAGHER: Well, we will show you the data, but --

MEMBER BANERJEE: The mesh resolved these?

MR. GALLAGHER: Yes, we picked the mesh size to look at the area of interest, and Francis will go into, you know, how that size was selected and the sensitivities that were done to verify this.

MEMBER BANERJEE: So you did mesh refinement for conversions?

MR. GALLAGHER: Yes, Francis, do you want to --

MR. KU: Yes, the current model we have is 400,000 elements, but we actually validated using a more finer mesh model which has more than 1 million elements.

MEMBER BANERJEE: And did you find conversions?

MR. KU: Yes, we actually find solution conversions. Compare the stress intensities between the two runs and they are pretty much the same.

CHAIRMAN SHACK: But again, Sanjoy, his local thinning areas are like 18 inches or 51 inches in diameter.

MEMBER BANERJEE: Right, that was the question.

CHAIRMAN SHACK: And he's using .75-inch mesh inside there.

MEMBER BANERJEE: Yes. So you think you sufficiently --

MR. KU: We have some slides showing the actual mesh in those locally-thinned areas.

MEMBER BANERJEE: Okay.

MR. KU: You see the mesh refinement in there.

MEMBER BANERJEE: All right. I'll hold my questions.m

MR. GALLAGHER: We have a lot of information in there.

MEMBER BANERJEE: Yes.

MR. GALLAGHER: You know, we can certainly get into whatever you need.

MR. O'ROURKE: So that concludes my discussion about the Oyster Creek drywell description. If there are any questions on the drywell description before I go in and talk about the shell thicknesses that we used in the 3-D analysis?

Okay. With that, we'll go to slide 11.

MR. WILKOWSKI: Excuse me. I've just got one comment. When you go through your description, can you describe the star truss boundary conditions well for us? And also, there's a lot of concrete; I think you've only modeled it on the bottom of the shell, and what boundary conditions there might be for the concrete and steel structure higher up and if there's some conservatism in ignoring some of those aspects.

MR. O'ROURKE: Francis can describe the modeling of the star truss, which is directly connected to the drywell, but the concrete is not. There's a gap in there. So the only concrete that we modeled was the concrete that's embedded where the shell is embedded at the bottom.

MR. WILKOWSKI: Okay. How big is that gap?

MR. O'ROURKE: Three inches.

MR. WILKOWSKI: Oh, okay.

MR. O'ROURKE: Okay? All right. On slide 11, we show the thicknesses used in the analysis for all the shell areas except the sandbed region, which I'll discuss starting on the next slide. For all the areas, and we've listed the cylindrical region, the knuckle, the various spherical portions and the two embedded sections in this slide.

For all of the areas except for the 676 mil embedded, the thicknesses were developed based on the ultrasonic thickness measurements taken from inside the drywell. For the cylindrical knuckle and spherical shells above the embedded portion the minimum general thickness was used for the analysis. For the 676 nominal embedded shell thickness, the thickness was estimated using the nominal thickness reduced by a 40-mil corrosion allowance. This is a shell that's been embedded ever since the concrete was poured.

Slide 12, which we looked at earlier, shows the thicknesses used as input to the 3-D analysis for the sandbed region. Based on our ultrasonic measurement data, we thought it appropriate to divide some of the bays into two areas. Mike mentioned elevation eleven-foot-oh. That was our dividing line. And in some of the bays we used different thicknesses for the split areas. Remember, the sandbed runs from vertically from elevation eight-foot-eleven to twelve-foot-three. Where we thought it was more realistic, we used the different thickness inputs above and below, and I'll provide a bay-by-bay discussion of those inputs in later slides.

MEMBER ABDEL-KHALIK: Excuse me. On the previous slide, where does the 40-mil corrosion allowance come from?

MR. O'ROURKE: The 40-mil corrosion allowance, if you notice here, I've noted the embedded region which is a 676 nominal thickness.

MEMBER ABDEL-KHALIK: Yes.

MR. O'ROURKE: The thickness that we used in the analysis was 636.

MEMBER ABDEL-KHALIK: Why 40 mils? Where do you get that number?

MR. O'ROURKE: It was an approximate one mil per year corrosion allowance that --

CHAIRMAN SHACK: You know, for the pH of the embedded concrete, for the high pH condition; we had a presentation on that at the subcommittee, that they estimated a corrosion rate of a mil a year and because of the high pH condition associated with the concrete.

MEMBER ABDEL-KHALIK: But I'm trying to understand, given the fact that there is sort of intimate contact, intimate support of the steel against the concrete in the bottom, how sensitive would the results be to the thickness in that region? I suspect they're not.

MR. GALLAGHER: Yes, before that, just to answer the original question, what Dr. Shack said, this 40-mil allowance we think is a conservative, you know, reducer in that input. There really shouldn't be any corrosion at all, because, you know, it's imbedded steel and concrete. It has a high alkaline poor water, if there is water in there and so on. So that's why we think, you know, adding or reducing it by 40 mils inputted the sensitivity that you might be thinking of, you know, versus what's actually there. So that's how we addressed that issue. We just conservatively reduced it by 40 mils.

MEMBER ABDEL-KHALIK: Now, would you expect the results to be significantly affected by the thickness in that region?

MR. GALLAGHER: No, we wouldn't. Maybe, Stan, could you -- so the question would be, you know, if that thickness changed much.

MR. KU: Based on the sensitivity study that we did, you know, it doesn't seem that that would be a very significant change in the safety factors.

MR. O'ROURKE: The other factor which unfortunately is not shown in the detail is that there is a ring support that is on the 1154 embedded portion of the drywell shell. The 636 is just a portion between the ring supports. So the support line actually comes through these ring support into the 1154 shell, which is why the shell is thicker.

MEMBER ABDEL-KHALIK: Okay. All right. Thank you.

MR. WILKOWSKI: Would that corrosion change your boundary conditions along the bottom?

MR. O'ROURKE: They modeled the boundary condition as fixed for that point. It wouldn't change that.

CHAIRMAN SHACK: But it's vertical fixed.

MR. O'ROURKE: Again, we thought 40 mils was a conservative estimate for that shell. As Mike said, it's likely to be thicker, but for the purpose of the analysis we made it 636. Does that answer the question?

MEMBER ABDEL-KHALIK: Yes. Thank you.

MR. O'ROURKE: Okay. Back on slide 12. We can bring this picture back up as needed. As I said, all of the thickness inputs are shown for both above and below elevation 11. We also show what Mike referred to as the locally-thinned areas, which we modeled in based on the external points. And again, they were modeled in to try to provide as realistic a model as possible so that we made sure that we analyzed this properly. And we'll discuss the locally-thinned areas in more detail in the presentation.

MEMBER ABDEL-KHALIK: The colors here identify the bays maybe, but what --

MR. O'ROURKE: The colors are just to distinguish the regions. They don't have a significance otherwise.

MEMBER ARMIJO: Your largest, thinnest region, that 696 in Bay 1, is that the way to interpret that?

MR. GALLAGHER: Yes. And then there's one 658 on Bay 13, which is an 18-inch circle.

MR. O'ROURKE: Right. That's an 18-inch circle at 658. The 696 is a 51-inch circle. That's the smallest, the thinnest 51-inch circle, yes.

MEMBER ARMIJO: The largest thinnest is a 696?

MR. GALLAGHER: Right.

MEMBER ARMIJO: And the thinnest --

MR. GALLAGHER: Would be Bay 13, right.

MEMBER ARMIJO: -- even though it's a smaller diameter?

MR. GALLAGHER: Right. Yes, there's two circle sizes. One is 18 inches, the smaller one, and the other is 51 inches.

MEMBER ABDEL-KHALIK: And this is from the outside?

MR. GALLAGHER: Yes, you're actually viewing this from the underside of --

MEMBER ABDEL-KHALIK: But I mean the thinning is --

MR. GALLAGHER: The corrosion from --

MEMBER ABDEL-KHALIK: The corrosion is from the outside?

MR. GALLAGHER: Yes, you know, the shell was here and then the sand was on the outside of the shell.

MEMBER ABDEL-KHALIK: But this ate into it --

MR. GALLAGHER: And so the corrosion was from the outside in. And so John's going to go through the measurements. We took some measurements on the inside of the drywell, the smooth surface, but they're UT measurements, so we get thickness. And then once the sandbed was accessed, we did some interrogation from the exterior to validate our interior measurements. And so we have both sets of data that we look at.

MEMBER ABDEL-KHALIK: The interior was not corroded?

MR. GALLAGHER: The interior was what?

MEMBER ABDEL-KHALIK: The interior was not corroded?

MR. GALLAGHER: That's correct.

MEMBER ABDEL-KHALIK: It's just outside?

MR. GALLAGHER: Right. Correct. Yes, where the sand was.

MEMBER ABDEL-KHALIK: And when you say 696, that's the remaining thickness of the shell for this large area?

MR. GALLAGHER: Yes, in that --

MEMBER ABDEL-KHALIK: Was that the thinnest spot of this?

MR. GALLAGHER: It's the remaining modeled thickness. Yes, if you look at --

MR. O'ROURKE: We believe it's thicker than that, but it's the thickness that we used in the model.

MR. GALLAGHER: Yes, when we go through that particular area, you'll see the data points we used and how we made basically an assignment of the entire area to a thinned value just so we could see what the effects were. So we think we greatly enveloped what's there, both in size and in depth, you know, thickness. And we'll go through that detail.

MEMBER BONACA: Did you evaluate why you have corrosion only in the specific areas? Is there any reason?

MR. GALLAGHER: No, Dr. Bonaca. If you recall how the water got in there, there's a trough at the top and there is some thought that the low spots were more towards this end of the containment. And so this area got more water more often, is the thinking. Because you can see, it does look like it's kind of, you know, ganged together on this quadrant versus say the other quadrants, you know? So that was the thought. But, you know, you could never pin it down to, you know, a particular cause. But that's the general thinking we had.

MEMBER SIEBER: That's speculation and it's also not important, right?

MR. GALLAGHER: Well, for the purpose of

this analysis we didn't think it was important because, you know, we --

MEMBER SIEBER: Because of the separation of this --

MR. GALLAGHER: And we looked at the entire sandbed.

MEMBER SIEBER: Right.

MR. GALLAGHER: So we didn't, you know, just limit it based on, you know, a limited --

CHAIRMAN SHACK: You did something to build up that curb at the top, right, if I recall?

MR. GALLAGHER: There were some repairs that were done and again --

CHAIRMAN SHACK: To prevent the water from coming over.

MR. GALLAGHER: And the primary was to put strippable coating on the reactor cavity to prevent the water --

CHAIRMAN SHACK: But I mean you did do something?

MR. GALLAGHER: Yes.

MR. O'ROURKE: Oh, yes.

MR. GALLAGHER: I mean, there were a number of things that were done and they were --

MEMBER BONACA: I imagine the monitoring

will be focused on that particular area.

MR. GALLAGHER: And what we do, Dr. Bonaca, is every four years or every other refueling outage we do all the points in the sandbed. So there's; John will go into the details, there's like 19 grids and there's like over 100 individual external points. And we go and look at all of those, the entire sandbed. So we're just not limited to, you know, particular bays or anything like that.

MR. O'ROURKE: And in fact that's the next slide that I've shown that illustrates where we take the ultrasonic thickness measurements. This slide was shown in the January 2007 subcommittee meeting. And we take these thickness measurements on an ongoing basis as part of our monitoring program. As Mike mentioned, every other year we do 100 percent. So this shows all of the points, and I'm going to describe these to you.

First of all, the squares and these smaller rectangles, those are the grid measurements that we take inside the drywell.

CHAIRMAN SHACK: you know, I know the 49-point grid is the six-inch-by-six-inch thing. What does the seven-point grid look like?

MR. O'ROURKE: It's a one-by-seven.

CHAIRMAN SHACK: Oh, it's a strip?

MR. O'ROURKE: Yes. Well, it's horizontal. It's like one row.

CHAIRMAN SHACK: Okay. Okay. One row of the --

MR. O'ROURKE: Right. Right. It's actually -- he's otherwise engaged, but I believe that they have a template that's just a single row.

CHAIRMAN SHACK: Rather than --

MR. O'ROURKE: Whereas the other is a templates that's a seven-by-seven grid. And the locations of the grids are marked in the drywell so that each time we go and take these measurements the grid is put in the same place so that we can duplicate the measurements that were taken. The grid has a -- the holes are the size, you know, plus a couple mils of the probe, so that you just put the probe in the hole and you take the measurement. And then they just, you know, take all 19 locations that we specified for ongoing monitoring purposes. So those are the internal grids that we take inside the drywell.

Now, the large vertical rectangles here represent the trenches. Now, these trenches were formed by removing concrete from the floor to allow us to gain access to the shell from the inside. And we take a series of 49-point grids going down the trench. Okay? And those are what we call the trench readings, trench data. You'll hear me refer to that.

MEMBER BANERJEE: Are those just the ones below the 11-foot level of the trenches?

MR. O'ROURKE: Well, the concrete floor inside the drywell is ten-foot-three.

MEMBER BANERJEE: Okay.

MR. O'ROURKE: So the trenches go from ten-foot-three down to a level that actually in one case goes below the sandbed. And although we take those readings and we trend those readings, the ones that we use in the analysis are the ones that are directly opposite the sandbed on the outside. And I'll talk about that when I get to that particular bay. That would be Bay 17.

MEMBER ARMIJO: Did you remove concrete to get that deep?

MR. O'ROURKE: Yes, we did.

MEMBER BANERJEE: And you did that internally as well as externally?

MR. O'ROURKE: No, no. That was

internal in the drywell.

MEMBER BANERJEE: Only?

MR. O'ROURKE: It's removed from the drywell floor.

MEMBER BANERJEE: So how do you get the triangles say between five and --

MR. O'ROURKE: Right. I was just about to finish the description of our program by mentioning that all of these triangles are the external data points that we take. That's a point reading that we take. And that is taken from the outside of the drywell in the sandbed regions.

MR. GALLAGHER: Yes, the floor inside or outside is lower than the floor inside the drywell. So these individual data points, once they're in the sandbed they're accessible.

MEMBER BANERJEE: So where is the lowest point in the sandbed region?

MR. GALLAGHER: If you look at this drawing here, this is --

CHAIRMAN SHACK: Eight-foot-eleven-inches is the bottom of the sandbed.

MR. GALLAGHER: Yes.

CHAIRMAN SHACK: Okay.

MR. GALLAGHER: The bottom red-dashed

line.

MEMBER BANERJEE: So the lowest triangles are right at the bottom?

MR. GALLAGHER: Or above the floor, yes.

MEMBER BANERJEE: Yes.

CHAIRMAN SHACK: What's confusing is you got to remember there's five feet of shell here. There's not a whole lot of elevation. But this sucker's a fairly big diameter. So there's a lot of metal hanging out there. I keep doing this mercator projection in my head and I get --

MEMBER BANERJEE: Yes, you've got the levels shown here. It's just that I --

CHAIRMAN SHACK: But just on this one I was curious about one thing, and that is I see thinning in the Bay 11 with those local measurements. I see yellow dots, but there's no local thinned region in Bay 11. I don't see any real thin dots in Bay 15, but you put in a locally-thinned region. I just wonder what the rationale for that was.

MR. GALLAGHER: Yes, and we'll go through in the individual points. Bay 13, I believe there's one that's like seven --

CHAIRMAN SHACK: Well, it was Bay 11

that concerned me most because it had no locally-thinned region, although a see a clump of yellow points there.

MR. GALLAGHER: Correct. And we'll go through the individual bays, but in that particular one we thought that the grid average that we used would be representative, because there's only a couple points there. And if you see, there's not many external points. The external points really we're interrogating what looked visually thin. And then if you remember, they were ground down. And so when they were actually measured they were even a little thinner than, you know, what was there. So you're actually measuring the thinnest of the thin. So one way to look at these external points, if you see a lot of external points, then it was because there was some, you know, thinness there visually. And that was interrogated. If there's very few external points, that means it generally looked pretty good. And so we think the grid data more represents that.

CHAIRMAN SHACK: And those particular points do overlap the grid.

MR. GALLAGHER: Exactly.

CHAIRMAN SHACK: So you're sort of

weighting the grid data over the --

MR. GALLAGHER: Exactly.

CHAIRMAN SHACK: Fair enough.

MEMBER BANERJEE: So, I didn't follow the explanation exactly, but can you just briefly say again why the internal points show thinning and the external points don't for bay level?

MR. GALLAGHER: Okay. So, and again John will go into detail, but basically Bay 11 -- what we were trying to show here is most of the points on Bay 11 are from the internal grid measurements.

MEMBER BANERJEE: Yes. Right.

MR. GALLAGHER: Even those yellow squares, those yellow squares are actually individual points in the grid. Okay? And so, but there's very few triangles, and most of them are green, which means they were thicker. So what I was saying was that when you see very few exterior points, triangles, that means when we went into the sandbed and looked externally there wasn't a lot of degradation. And so there's very few points to interrogate.

MEMBER BANERJEE: Yes.

MR. GALLAGHER: Where you see a lot of

points, like say Bay 1 and Bay 19, there was more degradation and therefore more interrogation.

Now, the point I was trying to make about the external points was that the external points, the way they were identified was you go into the sandbed, you look for thin areas. And then we actually had to grind it down to put the UT probe on. We had to prepare the area. So these external points, you can view them as the thinnest of the thin, biased-thin. And so that's why when we use that data for determining local thinned areas, it's biased on the thin side.

So in this particular case we think that the grids better represent the general thickness in Bay 11 versus the individual external points.

CHAIRMAN SHACK: But the location of the grids was just sort of laid out. That wasn't an informed decision. You didn't put your grids on what you thought were the most corroded places?

MR. GALLAGHER: There was some interrogation. What happened, Dr. Shack; and again, this was before the sandbed was accessed, there were several points that were taken at the curb, at the lower point inside the drywell in a bay. And so wherever the smallest point was, there was a cross that was put -- basically the grid was centered on that point. So the grids were identified as, you know, the thinnest general area in each bay. And that's why there's various numbers of grids and they're not all in like the same location in each bay, because it tried to determine where the thinnest areas were.

CHAIRMAN SHACK: And the external points are again also basically informed points? You're sort of looking at the shell?

MR. GALLAGHER: Yes, they were based on actual visual inspection and then --

CHAIRMAN SHACK: And I take which would look like thin spots to you?

MR. GALLAGHER: -- and then interrogation. So, Dr. Banerjee, did we answer your question?

MEMBER BANERJEE: Well, then I'm puzzled by Bay 19 where you've got lots of internal points which show thinning and no external points. Am I right?

MR. O'ROURKE: Well, they may be masked by the internal points. We have the data. So we're working off the data. This is just an illustration to kind of show the relationship between the grids and the external points and what not.

MR. GALLAGHER: But 19 is the first one we discussed, and it is based off the grid averages.

CHAIRMAN SHACK: Right. When you get to slide 26, you'll see the Bay 19 in more detail.

MR. GALLAGHER: It was 16.

MEMBER BANERJEE: Okay.

MR. O'ROURKE: And Mike made an important point here that the colors here, the small yellow squares, they're values of within the internal grids. All right? So they are considered as part of the thickness by virtue of using the grid averages. Okay? It's the triangles that are on the external.

MEMBER BANERJEE: Right.

MR. GALLAGHER: But I think when we go through the details, you'll see Bay 19 was treated similarly to Bay 11, which is that the grid averages are used. And, you know, you can see that they're similar and that even the thin points are within the grid.

MR. O'ROURKE: And we did model locally-thinned area in Bay 19 based on the external data points.

MEMBER BANERJEE: So Bay 11, Bay 17 and

Bay 19 mainly showed -- from the internal grid UT measurements showed some thinning? Those are the yellow squares? Bay 13 is where you have yellow and red triangles primarily, right?

MR. GALLAGHER: Yes.

MEMBER BANERJEE: So can you explain at some point how are you interpreting --

MR. GALLAGHER: Right. Bay 13 has a locally-thinned area that encompasses the lowest external points measured, which would be the red one and a couple of the yellow ones. And I have an illustration of the locally-thinned areas and the external points that are within and around that area. And then I'll explain, you know, which ones we used for our average for that area.

MEMBER BANERJEE: And I guess Bay 1 also has some externally-thinned areas.

MR. GALLAGHER: Bay 1 we have an externally -- yes, we have a locally-thinned area in Bay 1.

MEMBER ARMIJO: And maybe this is just a problem with the illustrations, but it seems that Bay 15, the chart on page 13, is inconsistent with the chart on 12, because on 13 you have no points less than 736. Everything's green triangles. But yet in your chart on page 12 you show a 711 region for Bay 15.

MR. O'ROURKE: Well, as I said, on 13 that triangle may have been masked by the green --

MR. GALLAGHER: Well, it's the 711s. Bay 15 is what you're referring to.

MEMBER ARMIJO: Okay. Fifteen. Okay. Yes.

MR. GALLAGHER: Yes, and there's one point and it's masked in this general depiction, but there was one point that was less than 736. It was 711. And we centered a locally-thinned area on that.

CHAIRMAN SHACK: Exactly. Slide 29.

MR. GALLAGHER: Yes, and we'll get to that.

CHAIRMAN SHACK: We'll get to that. Okay.

MR. GALLAGHER: One thing I guess before we move on, Dr. Khalik, we did get the answer to your question on the non-degraded.

MEMBER ABDEL-KHALIK: Yes.

MR. GALLAGHER: Okay. So again, this is the Sandia analysis. It's a different model. It's a different analysis. But the Sandia did a non-degraded. And this was requested by the staff. And if you look want to look at the report in the future, it's on page 70, table 4-2, and it's entitled, "Buckling Evaluation in the Sandbed Region for the Refueling Load Case With No Degradation," which is, I think, the question you had. And the effective safety factor was 3.85 in the sandbed. Okay?

MEMBER ABDEL-KHALIK: But that's sort of a more conservative analysis. It's not identical analysis to --

MR. GALLAGHER: It's not identical, but it just --

CHAIRMAN SHACK: But in your February presentation you give us a Sandia analysis with a modified capacity factor.

MR. GALLAGHER: Right.

CHAIRMAN SHACK: And that kicks it up to like 4.5.

MR. GALLAGHER: Yes, they did not use the modified capacity reduction factor and, yes, so I think, you know, that was that chart we showed that --

CHAIRMAN SHACK: Yes, and so that's the closest we have to an apples -- I mean, even then there's still differences.

MR. GALLAGHER: Right.

CHAIRMAN SHACK: But if you were looking for the best estimate of what we have for the un-degraded shell, it would be on the order of 4.5.

MR. GALLAGHER: I think that's probably reasonable. And then we're showing about three-and-a-half, you know, in the degraded condition.

MEMBER ABDEL-KHALIK: All right. Thank you.

MR. O'ROURKE: Okay. I'd like the next slide. Five-fourteen summarizes the 19 internal grid locations that I just described on the previous slide. These were shown by the squares and the small rectangles as the 19 grid locations. As Mike mentioned, we interrogated more than 19 locations. However, the 19 were the thinnest. They were picked for ongoing monitoring. And we do those measurements every other year.

MR. GALLAGHER: Every other outage.

MR. O'ROURKE: Every other outage. Thank you.

For each of these grids I've noted the number of measurements taken in the grid and also the average thickness of those measurements based on the 2006 measurements. Okay?

And the next slide shows the similar data for the trench measurements, but also shows you --

MEMBER BANERJEE: What's the units for that?

MR. O'ROURKE: Mils. Mils. All the measurements are in mils.

Oh, inches. I'm sorry. I do have a decimal in there, don't I?

MEMBER BANERJEE: Well, just the point.

MR. O'ROURKE: Thank you. Thank you for that clarification. Inches.

Slide 15 shows the number of grids that we take in the embedded, in the trenches. So somebody asked about how much concrete we removed. You know, if you've got a seven-inch grid that you put in there, and we've got seven of them, so there's almost 50 inches of concrete that was removed in Bay 5.

In addition, in 2006 we removed some additional concrete and we exposed portions of the embedded shell that previously had never been exposed. You know, all this time we've been monitoring the seven grids in Bay 5. But in 2006, we actually took out some additional concrete. That's referred to as the Embedded EMB Grid, and I'll talk about that when I talk about Bay 5. We do use that data, since it was the first time that we'd ever seen that portion of the shell.

MEMBER ARMIJO: Is that region still accessible?

MR. O'ROURKE: Yes, it is. Yes, and I believe our commitment is to continue to take measurements until we see no water for two outages.

MR. GALLAGHER: Yes, if you remember, there was some debate with the ACRS. There is a license condition. We have to do monitoring. And then once we verify that there's no water inside the drywell, because you know, you do have some equipment leakage and that type of thing that we could apply to the staff to refill in the trenches. You know, because I think there was some concern with some members here that, you know, it's not -- the original design is to have concrete there, so it's probably better to have concrete there. And we agree and we just had it for monitoring. So when we want to fill those in, we would just have to get some staff approval and then we would go ahead forward with that.

MEMBER BANERJEE: So all the corrosion you found is in the sandbed region?

MR. GALLAGHER: Correct.

MEMBER BANERJEE: You've never seen any corrosion anywhere else?

MR. GALLAGHER: Right. Okay. Dr. Shack's reminding me, the water was on the outside of the shell, so there is some degradation, very small, up in the upper drywell area, and our monitoring program also monitors those. So we have 11 grids, you know, up in the cylinder and that type of thing. We also took some data on the knuckle area and they were the primary areas. And when we say we do all measurements, we not only do the sandbed, but we do the grids up in the upper drywell. Now, that area, you know, there wasn't much to retain the moisture. You know, there's some material that's in the gap, which was like a construction aid, but there wasn't much to maintain the moisture. So the data was showing that as --

MEMBER BANERJEE: There was very little corrosion anywhere else?

MR. GALLAGHER: Very little, yes. Very little.

MEMBER BANERJEE: This is the main area?

MR. GALLAGHER: Yes, the sandbed region, because the sand was there and, you know, the sand was wet, until we went in and did the correction action there was corrosion. Since we removed the sand and did the corrective action, you know, the three-coat epoxy system, there's been no corrosion.

MEMBER BANERJEE: And how many monitorings have you done?

MR. GALLAGHER: As part of the license renewal we did a complete set of data in 2006 and then we repeated it in 2008, and then our commitment is to do it every other outage. Before 2006, you know, we showed all the data. There was data going back to 1986 or '84. And so you saw, you know, the degradation until the corrective action and then it was flat lined. From 1992 on it was flat lined.

MR. O'ROURKE: And we had showed those trend plots in the previous meeting.

MEMBER BANERJEE: So in 1992 you removed the sand?

MR. GALLAGHER: Right, and put the epoxy coating on.

MR. O'ROURKE: And to be conservative, the inputs that we used for the model for the non-sandbed regions are the lowest readings that we have regardless of what year they occurred.

MEMBER BANERJEE: When did you put the internal trenches in? Was that '92 as well?

MR. GALLAGHER: The first data on the trenches, Pete, do you recall that? Was it --

MR. TAMBURRO: It was (off microphone.)

MR. GALLAGHER: Yes, you know, it was prior to 1992. It might have been 1991, but it was in that time frame. And then we reinterrogated it in 2006 and 2008.

CHAIRMAN SHACK: Again, please come to a microphone when you make a comment.

MR. GALLAGHER: Yes, that was Pete Tamburro. Pete, could you just say that again?

MR. TAMBURRO: Sorry. Pete Tamburro. The trench data was taken prior to 1992. And I'll check my records for the exact date.

MEMBER BANERJEE: So if I understand it, the corrective action was taken in nineteen when?

MR. GALLAGHER: 1992.

MEMBER BANERJEE: '92?

MR. GALLAGHER: Yes.

MEMBER BANERJEE: And since then no corrosion has been seen?

MR. GALLAGHER: That's correct.

MEMBER BANERJEE: And you've monitored it several times?

MR. GALLAGHER: That's correct.

MEMBER BANERJEE: And you had the trenches at that time, in '92?

MR. GALLAGHER: That's correct.

MR. O'ROURKE: All except that little portion I described in Bay 5 that we excavated in 2006. Otherwise, the rest of it was available.

MEMBER BANERJEE: Did you find any corrosion in Bay 5?

MR. O'ROURKE: No.

MR. GALLAGHER: And just one minor point of clarity, when we did the coating inspections last outage, there was one blister and that blister was, you know, interrogated and re-coated. So there was we calculated, about a three mil dime-size blister, you know, from our inspection last outage.

MEMBER BANERJEE: This was a visual that you did, or something?

MR. GALLAGHER: Yes, and that's all we've --

MEMBER BANERJEE: All you've seen on the --

MR. GALLAGHER: Yes.

MEMBER BONACA: You haven't really stopped the source of water? You had water accumulating in the sand region. Do you find still wetness out there?

MR. GALLAGHER: Last outage we did have some leakage from the reactor cavity that got into the sandbed because the strippable coating delaminated on us. We did a re-cause evaluation on that and basically what happened was we had changed the process up on the refueling area. There's a pump you put into the cavity to do some clean up. And that pump was reoriented differently than normal and basically the water discharge, you know, blew onto the strippable coating and delaminated some of it and some water did get in the sandbed. The outage before that, it was one we talked to you about at the ACRS subcommittee meeting, there was no water got in the sandbed because the leakage rate was, you know, able to be handled by the reactor cavity drains. So we put corrective actions in on the refueling floor on this equipment set up so that, you know, we shouldn't repeat that again.

MEMBER BANERJEE: How good, or let's say how complete are the visual inspections of the coating you put in the sandbed region? You said you found a dime-sized blister. If there are other blisters, are you pretty sure that you would always see them?

MR. GALLAGHER: Yes, and, I mean, those inspections are very thorough. We look at the entire surface area of the whole coating, all 10 bays. And in this particular case, once we found that we actually did a reinspection to make sure as part of the extended condition, and we didn't find any others.

MEMBER BANERJEE: But this is done with some sort of a light probe or something?

MR. GALLAGHER: No, people go into the sandbed.

MEMBER BANERJEE: People actually go into it?

MR. GALLAGHER: Yes.

MEMBER BANERJEE: Wow.

MR. O'ROURKE: He's VT-certified.

MR. GALLAGHER: You go into the sandbed and there are access ports drilled through the concrete, you know? And you go into the sandbed and you can get in there, you can go in there and you do --

CHAIRMAN SHACK: It's 15 inches. It

sounds like fun.

MR. GALLAGHER: Well, there are certain size restrictions. I mean, you know, tall folks and those that are a little more stout, you know, don't volunteer for the work.

CHAIRMAN SHACK: Yes, right. All right.

MR. GALLAGHER: But our inspectors, they go in there and many of them have done it many years. And you can go and you do a complete visual inspection of the coating.

MEMBER BANERJEE: And this coating is what, brownish is color or something?

MR. GALLAGHER: It's actually like it, was is it a gray? Yes, it was like a whitish, you know, off-white.

MEMBER BANERJEE: But it's evident if you're getting some blistering?

MR. GALLAGHER: Yes.

MEMBER BANERJEE: It's easy to see?

MR. GALLAGHER: That's right.

MEMBER BANERJEE: And there is no potential degradation mechanism from inside the coating which you can't see visually? And is there a lot of experience with this coating just showing that the degradation is likely to occur from outside and can be seen on visuals?

MR. GALLAGHER: Yes. Yes. Now, however, we did do a root cause on this blister we had because, you know, our inspections are looking for this kind of thing.

MEMBER BANERJEE: Right.

MR. GALLAGHER: And what we identified was that there was some chlorine in the area of this blister. And so the root cause suggests like an osmotic absorption of moisture because of the chlorine that's there. The chlorine was probably there from the salt in the sand. And so it probably would have initiated when the coating was applied in 1992. Again, our ongoing monitoring program will make sure that if we have any further type things, we can do those and do spot repairs. The loss in that area, it was only a three-mil loss, you know, the size of a dime. So that's basically what we found.

MEMBER BANERJEE: Well, I guess until it really breaks through, water ingress can't occur, right?

MR. GALLAGHER: Right, and that's the protective coating and that's the whole idea of that, yes.

MEMBER BANERJEE: And there's good experience with this stuff?

PARTICIPANT: And this occurred in what bay?

MR. GALLAGHER: I think the blister was Bay 11.

MEMBER BANERJEE: And other people have probably done this, so the experience with this coating material indicates that it lasts and you don't have to --

MR. GALLAGHER: Yes, and we had a coatings expert here. John Cavalo, during the subcommittee meeting, went through that presentation. And basically we do the coating inspections per IWE. And as long as we do the inspection and do maintenance, the coating can last a very long time. And so that's what our program that was --

MEMBER BANERJEE: Where has it lasted the longest up to now?

MR. GALLAGHER: I'd have to pull up some of his information on --

MEMBER BANERJEE: Thee is industry experience which is longer than yours.

MR. GALLAGHER: There is experience on

coatings. And now, I don't know on this specific coating, because you know, coatings do change over time. But this is a very good service life and, you know, continues. We had shown pictures to the subcommittee and so you go to see, you know, how good it was.

MEMBER BANERJEE: But this has lasted 17 years up to now, right?

MR. GALLAGHER: Yes, and still, you know, very good condition.

MEMBER BANERJEE: Pretty good?

MR. GALLAGHER: Yes.

MEMBER BANERJEE: And you think it will last another 20 after you renew the license?

MR. GALLAGHER: It will last a long time as we do, you know, inspections and spot repairs. And that would be our --

MEMBER BANERJEE: If necessary you can strip it and you can put --

MR. GALLAGHER: We could probably do other more --

MEMBER BANERJEE: yes, if it's necessary.

MR. GALLAGHER: If it's necessary, yes.

MEMBER BANERJEE: All right. Thank you.

MR. O'ROURKE: We'll be back on to talk about the bay-by-bay thicknesses then. I'd like to start on slide 16.

MR. GALLAGHER: John, sorry.

Pete just told me, Dr. Banerjee, the first time we took data in the trenches was 1986.

MEMBER BANERJEE: Okay. Thanks.

MR. GALLAGHER: Sorry, John.

MR. O'ROURKE: No problem.

I'd like to start the bay-by-bay thickness discussion with Bay 19. We monitor three nominally 49 point internal grids in this bay. And to get the thickness of the bay, we use the average of those three grids as to thickness for the entire bay. And that is 826 mils.

Next slide. For Bay 1 we monitor one seven-point grid in this bay. And although visual observation confirmed the presence of historical corrosion, the grid readings indicated near nominal thickness. So we conservatively estimated the thickness of Bay 1 to be the same thickness as Bay 19. So that's why you see Bay 1 and Bay 19 both at 826.

MEMBER ARMIJO: John, I'm sorry, I'm still confused here. Bay 19 you say you used the average thickness of 826, but yet on your slide 12 you have this large 50-inch diameter at 720.

MR. O'ROURKE: Correct. So let me say that the discussion for the next 10 slides, one per bay, is on the general area thickness. And then I will have slides that will talk about the locally-thinned area. Okay?

MEMBER ARMIJO: Okay. Thank you.

MR. O'ROURKE: So that will be the first slide and the locally-thinned area will be Bay 19. Okay?

On slide 18, we do have a typo. I apologize. We do have a typo on slide 18. The third bullet there should say Bay 5, not Bay 3. I'm sorry, that typo is on 19. We are talking about Bay 3. I put it on the wrong slide. Sorry. Yes, it's slide 19. Slide 19 has the typo.

MEMBER BANERJEE: Oh, not --

MR. O'ROURKE: Not slide 18. Sorry. Yes, slide 19, third bullet should say Bay 5. And slide 18 is correct.

MEMBER BANERJEE: Oh, that's --

MR. O'ROURKE: And I'll mention that when we get to the next slide. Okay.

On Bay 3 we monitor one seven-point

internal grid in this bay also. The grid readings indicated nominal or above nominal thickness, so we did use those average grid readings as a thickness above elevation eleven-foot-oh. Below eleven-foot-oh, some historical corrosion was observed, so we conservatively estimated the thickness of that portion of the bay as the average between Bay 1 and Bay 5, which is 950 mils. So we used 1180 above and 950 below for that bay.

Now on slide 19 for Bay 5, with the typo in the third bullet which should say Bay 5, Bay 5 we monitor the one seven-point internal grid and we also have the seven trench grids that I had previously described, each nominally 49-point grids. We used the average of the seven-point grid as the shell thickness for the area above elevation eleven-foot-oh.

MEMBER ABDEL-KHALIK: Back to the previous slide. So in cases where the measurement was actually slightly higher than the nominal thickness you used to measure values, is that correct?

MR. O'ROURKE: Yes, we did.

MEMBER ABDEL-KHALIK: So, you know, if the measurements were higher, you just used the nominal value to allow for any tolerances in measurements?

MR. O'ROURKE: No, we used the average of the grid, 1180. It is slightly above nominal, but it was the average for the data that we took.

MR. GALLAGHER: Yes, and we thought, you know, for consistency, to again get the actual margin, and we had data like that, we would just use it. You know, we did not use any -- John, when he goes through the local, we didn't use any thick points in these thinned areas. So we think --

MEMBER ABDEL-KHALIK: No, I understand. I mean, not just looking at the average or sort of the broad area values.

MR. GALLAGHER: Yes.

MEMBER ABDEL-KHALIK: And what you're saying is that he used the measured values --

MR. GALLAGHER: Right.

MEMBER ABDEL-KHALIK: -- whether or not they're greater than the nominal values.

MR. O'ROURKE: That's correct. And you'll see that on Bay 5 also. The seven-point grid average was 1185, and we used that. But remember, we're only using that above elevation of eleven-foot-oh.

MEMBER ABDEL-KHALIK: Yes, I understand that.

MR. O'ROURKE: And we have a different value for the lower portion of the bay, which would be eleven-foot-oh down to eight-foot-eleven. Okay?

Bay 5, though we did use the seven-point internal grid at 1185 for above eleven-foot-oh, since we had the trench in Bay 5 and had a lot of data in the trench, we averaged the trench data and we used the top five grids. This is where I mentioned that the trench actually went below the level of the floor of the sandbed. But we only used the trench data down to the floor, which is the top five grids. And that averaged out to 1074 mils.

MEMBER BANERJEE: So is 1074 the nominal, close to the nominal?

MR. O'ROURKE: Eleven-fifty-four would be the nominal thickness of the plate.

MEMBER BANERJEE: This is thinned down slightly?

MR. O'ROURKE: Slightly thinner, yes. Yes.

MEMBER SIEBER: If you wanted to be ultra-conservative, instead of using the average you could have used the lowest thinnest part. Is there a reason why you felt that the average was adequate as opposed to the --

MR. GALLAGHER: The thinnest from the trench data?

MEMBER SIEBER: Yes, the thinnest measurement.

MR. GALLAGHER: No, just for consistency. You know, we averaged when we had grid data, because there's many, many points. So we just took the averages.

MEMBER SIEBER: So you treated the analysis of the entire structure based on averages and then looked at local thin points? Is that how I should interpret that?

MR. GALLAGHER: Correct. So the internal data is based on grids which are multiple points. We use that for general thickness. And then the external data points John will get into, which are really the thin, the thin biased-thin, we use as inputs to determine the size and the thickness for the local areas.

MEMBER SIEBER: I understand what you do. I got to think about it a little bit.

MR. GALLAGHER: Right.

MEMBER BANERJEE: So your grids over

which you average are quite a bit larger than the mesh in the finite element analysis, is that right?

MR. GALLAGHER: Yes, they're six-by-six-inch grids, which are larger than mesh.

MEMBER BANERJEE: So, I mean, to be consistent with the initial conditions or whatever you put into this finite element analysis, you have averaged your measurements to the mesh size used? I mean, in a way that's the maximum resolution you can get, right, because that's what you did your finite element analysis? So there are two questions: One is was there -- so if you took this grid data and you looked at it in detail, and you averaged it so that it was consistent with your finite element analysis, would you get a thinner region than the 1074, say, just the last number there? Do I make my question clear, or don't I?

MR. GALLAGHER: No, I think I know what you're --

MEMBER BANERJEE: Yes.

MR. GALLAGHER: So when you step back and look at how the grids were determined and located, so they were located based on taking some multiple measurements, finding the thinner locations, and then centering the grid around that.

And so what we think is, on each bay that the grid average would be a biased-thin general area thickness. And so that's what we would use. The trench data provided us a lot more information. And we only have the two trenches. We have the trenches in Bay 5 and 17. So that provided a lot more information. And, you know, so we were able to use that as the input for those two particular bays. But I guess what we're saying is that the grids, you know, should be a thin general area representation and we were able to customize by having the individual bay values in there, which was what we were trying to do to develop a more realistic model, you know, versus the uniform thickness model that we had in our licensing basis.

So I don't know if I answered your question, but that's kind of what we did.

MEMBER BANERJEE: Well, in more general terms my question is, how did you represent the data that you got from your measurements in your finite element analysis? So that needs to be addressed at some point.

MR. GALLAGHER: Okay.

MEMBER BANERJEE: And, you know, how did you average it, or what was the data treatment as input into your finite element analysis? And we can address that when we --

CHAIRMAN SHACK: Well, that's what he's telling you know, the general areas.

MR. GALLAGHER: Yes. So simply what we did was based on the data we had, we assigned -- which we think is biased to thin for the general area, we assigned it to the entire location, the entire area. So for instance, that 1175 --

MEMBER BANERJEE: Yes?

MR. GALLAGHER: -- excuse me, 1185 in Bay 5 that John just went through. So that was based in the measurements John talked about. And so we assigned that value to the entire elevation of eleven foot, the entire sandbed plate. So you see that entire orange area. It was assigned to that entire area. Now we think that most of that area is thicker than that generally, because we identified this grid to be, you know, biased-thin, to measure the thinner areas. And then the 1074 -- so we had a trench, but now if you can imagine, you know, it's a six-inch slice of that. And again, we took the data in and we assigned it to the entire bay below an elevation of eleven foot. The mesh sizes that Francis will get into then were determined based on modeling in the area of interest. So those mesh sizes for the locally-thinned areas are three-quarters of an inch and they were an inch-and-a-half for the general bay. You know, so that's how that was done. But the entire areas that we're showing you here were assigned that based on the grid data or the trench data that we took.

MEMBER BANERJEE: I guess it would help me at some point; it doesn't have to be here, maybe it can be even done in an off-line sketch by the people who set up the finite element analysis, to show -- let's say, here is a grid and this was the measurement grid, and this is the finite element mesh, and we had -- from this measurements this is how we assigned that value for that mesh point.

MR. GALLAGHER: Okay. I think Francis --

MEMBER BANERJEE: I think that's all I need.

MR. GALLAGHER: Francis can get to it. Yes. In the next section we go into the model and Francis can do --

MEMBER BANERJEE: Right.

MR. O'ROURKE: Okay. Slide 20 for Bay 7. We monitored one seven-point internal grid in this bay. The grid readings indicate near nominal thickness. So we used the grid average readings as the thicknesses above elevation eleven-foot-oh. Below elevation eleven-foot-oh we estimated the thickness of that portion of the bay as the average between Bay 5 and Bay 9, which was at 1034 mils.

On slide 21 for Bay 9 we monitored two internal grids, one 48-point and one seven-point. The 48-point is a 49-point grid. We did get one point. So we monitored those two internal grids. And for the thicknesses above elevation eleven-foot-oh, we took the average of those two grids. That's 1074 mils. But below eleven-foot-oh we took a conservative approach and only used the smaller of the two grid averages. So we used 993 for the general area below eleven-foot-oh in Bay 9.

For Bay 11 we monitored two nominally 49-point grids, internal grids in Bay 11. And we felt that this bay had some corrosion both above and below eleven-foot-oh, so we used the average of the two internal grids as the general thickness for the entire bay at 860 mils.

For Bay 13 we monitor three internal grids in Bay 13, two 49-point and one seven-point. The seven-point grid indicated near nominal thickness. So we conservatively did not use that data in our thickness computation. We averaged the two 49-point grids and we used that thickness both above and below elevation eleven-foot-oh. And that was 907 mils.

For Bay 15 we monitor one 49-point internal grid and one seven-point grid. We use the average of those grids for the thickness above elevation eleven-foot-oh. And below elevation eleven-foot-oh we estimated the thickness of that portion as the average between Bays 13 and 17, which is 935 mils.

And then in Bay 17 we monitor two nominally 49-point internal grids. We also monitor a grid at the edge of the bay and we trend that data. That's noted as grid in the summary of 17 underscore 19, because it's between Bays 17 and 19. But we don't use that. We trend it, but we don't use that information for determining the thickness. We average the other two grids in elevation eleven-foot-oh. And similar to Bay 5, we have a trench in Bay 17. So for the thickness below elevation eleven-foot-oh, we use the average of the six nominally 49-point grids in the trench as the average below eleven-foot-oh.

MEMBER ABDEL-KHALIK: I guess I'm just trying to understand the logic for using average values for neighboring bays. The implication of something like that, that you have a phenomenon that's sort of gradually changing over a long length scale that would allow you to average, but all indications suggest that this is a localized phenomenon. Could you perhaps comment on the logic behind using average values for neighboring bays as characteristic numbers for a specific bay?

MR. O'ROURKE: Certainly. Right. So for instance, I'll back up to slide 24, for instance for Bay 15.

MEMBER ABDEL-KHALIK: Okay.

MR. O'ROURKE: So as I mentioned, we monitor two grids in Bay 15. And we took a look at the data that came out of that average and we felt that that was certainly representative of the thickness above elevation eleven-foot-oh. But for conservatism, we said, you know, we felt that we needed to have a different number below eleven-foot-oh. So the good data, we felt we had good data for the two adjacent bays, and because it is a continuous metal structure, we felt that we could conservatively estimate the thickness using the average of the two adjacent bays.

MEMBER ABDEL-KHALIK: But that's sort of the heart of my question.

MR. O'ROURKE: We tried that. We went back to the grid, what we felt was good grid data, you know, particularly in the case of Bay 17 where we had grid data all the way down the trench, you know, and where we felt that the grid data was representative. But we really wanted to get it to be a little bit finer tuned perhaps, and that's why we used the average.

MR. GALLAGHER: Yes, if I can comment a little bit on this. So, when you step back and you look at the grids and the external point interrogation that was done -- so say for Bay 15, like John said, the grids we believe are representative of the local condition in that bay, and that was validated by the grid data that was taken on the internal, but then some interrogation -- once the sandbed was accessed to, you know, look at thinned areas. And we debated this internally. We could have just assigned the entire bay to 1062. And we had thought about doing that. But what we thought was, since we had in the cases, if we had adjacent bay data, particularly from the trench because we thought the trench was good data, we thought it would be conservative to, you know, bias them down, the lower elevation down based on some data that we interrogated from the adjacent bays. And we just blended it just as an average. But we think we could have justified that, you know, again to get a realistic depiction of the margin, that we could have just simply assigned the entire bay that value. But we didn't. That was our thought process.

MEMBER ABDEL-KHALIK: Okay. Thank you.

MEMBER BANERJEE: I guess I'm still trying to understand. When you said "grid," you mean a lot of point measurements done on a grid?

MR. O'ROURKE: Grids are either seven-point grids or 49-point grids.

MR. GALLAGHER: So the 49 would be a six-by-six-inch grid, seven-by-seven, so 49 points.

MEMBER BANERJEE: Okay. And what's the area over which the point measurements are made typically?

MR. O'ROURKE: The circles where the probes are inserted to obtain the thickness measurement are on one-inch centers.

MEMBER BANERJEE: So you interrogate a

one-inch area typically?

CHAIRMAN SHACK: The probe is more like three-eighths of an inch, I think.

MR. O'ROURKE: Yes, the diameter of the probe is approximately three-eights of an inch. And the template, as I mentioned earlier, the holes are just slightly larger than that so that the probe just kinds of fits into the hole and takes a measurement for that point on the grid.

MR. GALLAGHER: But on one-inch centers, like John said. So it's a seven-by-seven grid.

MEMBER BANERJEE: Right. Yes, but the probe is three-eighths inch?

MR. O'ROURKE: Yes.

MEMBER BANERJEE: Ultrasonic beam that goes in.

MR. O'ROURKE: Well, the probe head, you know, is three-eights of an inch. It fits in the circle and then the beam will get you the thickness.

MEMBER BANERJEE: And this is a pizeocrystal which vibrates and it picks up the --

MR. GALLAGHER: The UT measurement?

MEMBER BANERJEE: Yes. Yes.

MR. GALLAGHER: I'm not a UT --

MEMBER BANERJEE: Right. Well, but

there are other ways you could do it.

CHAIRMAN SHACK: No, it's a standard back wall reflection off of --

MEMBER BANERJEE: It's a back wall? Okay.

MR. O'ROURKE: We did have our UT expert previously in the subcommittee present that information.

CHAIRMAN SHACK: It's a UT measurement you can believe, unlike many of them.

MEMBER BANERJEE: Well, I'm skeptical about everything, you know? I'll start with that premise.

MR. O'ROURKE: That's my summary for the ten general area thickness measurements and how we arrived at those numbers.

CHAIRMAN SHACK: Just to address that, too. I mean, I think you do have to include the fact that you have your visual eyeball integrator looking at these surfaces to tell you that Bay 15 doesn't look like an outlier and using these averages, you know.

MR. O'ROURKE: Yes. Right.

CHAIRMAN SHACK: We simply don't have enough data to assign it point-by-point in the finite element grid. I mean, but you have to do some kind of integration by visual inspection here. This would be very different if we had no other knowledge other than these data points, but you can see the surface.

MR. O'ROURKE: Right. Right. And the other factor, you know, in Bay 15, if you assign that 1062 to the entire bay, you'd basically have a hump in the metal, because we have 907 on one side and 963 on the other side. So visually we don't believe that there's any hump in that, so that's what kind of led us to saying, okay, fine, you know, 907, 063, we'll take the average as a transition between the two. You know, we observed no humps in the sandbed region.

MEMBER ABDEL-KHALIK: That's sort of interesting. So if you have two bays in which you have a large difference in the global thickness value for that particular bay, what do you do for the node that's right at the interface between the two bays?

MR. KU: The thickness changed at interface will be a step change.

MEMBER ABDEL-KHALIK: So you would have a step change in the node thickness?

MR. KU: Yes.

MR. GALLAGHER: And if you think about, you know, whether or not within the same bed you have that, you have it from the sandbed itself going to the next plate up, you know. So like, for instance, Bay 11 is at 860 and then the next plate up is nominal 1154. So, you know, you would have a transition there, and that's all modeled as a step.

MR. WILKOWSKI: So, where you have these thickness changes that are occurring in your thin shell finite element model, do you also offset the mean radial location of the shell to account for the corrosion only being on the OD surface?

MR. KU: No, we based the entire model for consistency. We used the mean radius.

MR. WILKOWSKI: Kept the mean radius of the sphere.

MR. KU: Right, kept the mean radius. Right.

MR. WILKOWSKI: Okay.

MEMBER ABDEL-KHALIK: And just centered the thickness around that mean radius?

MR. GALLAGHER: Yes.

MR. WILKOWSKI: Do you try to account for that eccentricity on the buckling effect at all?

MR. KU: No, because when you look at the model, the size of this locally-thinned region has a 35-feet radius. That's 420 inches. And the shell is only like less than one-inch thick. So if you're trying to calculate the ratio, whether to use the actual mean radius or the general shell thickness, you get a difference of about .1 percent in the radius.

MR. WILKOWSKI: In the radius?

MR. KU: So it's very negligible in the analysis. That's why we say for consistency we used the general mean thickness in the model.

MR. WILKOWSKI: Yes. Okay.

MR. O'ROURKE: Okay? So moving from the discussion of the general area thicknesses into the discussion of the locally-thinned areas, the next five slides will illustrate the locally-thinned areas that we modeled in five of the bays and how these areas relate to the external point UP readings.

We modeled the locally-thinned areas and the size and thickness of these areas based on the external point readings. And these locally-thinned areas are consistent with areas of interest previously evaluated and enveloped the thin external point readings. They're conservative since the circles encompass large areas as compared to the point readings and the shell thicknesses within these areas are known to be greater than the average point readings used in the analysis. And we are showing up here Bay 19. And the example is that for Bay 19 we modeled a 51-inch circle in Bay 19. And we took the numbers shown in red, the 712 and 728, which are the thinnest points in that circle and we averaged those to get 720. And that's the thickness that we used for the entire 51-inch circle. Even though you see a point here that's 883, one over here, 940, one here at 936, we conservatively took the thinner points. And that's a, you know, somewhat judgment. We use two here, we use three in another bay, we use four in another bay as representative thicknesses for the entire circle.

MEMBER ARMIJO: What about your data points that's 721 way out there that's not in red?

MR. O'ROURKE: Right. Not in red means that -- now, first of all, it's outside the evaluated area which is represented by the 51-inch circle. That was evaluated separately in the calculation. And for the 51-inch area, for the locally-thinned area, we only used the thinner points that were within the circle.

MR. GALLAGHER: And the fact, Dr. Armijo, that there's just a stray point out there means that that was when it was visually, you know, looked at for areas to interrogate. There was only that one point, so in general the area was, you know, less degraded. And, you know, just a point of emphasis of what John was trying to say, in our licensing basis analysis we evaluated areas that were less than 736, and so we had evaluated areas. And so what we simply did to keep consistency is that for those evaluated areas we just encompassed the entire area and assigned a value based on the thinnest points to that. So that 721 wasn't an evaluated area because the area around it was much thicker.

MEMBER BANERJEE: So 721 did not have any surrounding areas which were in the 700s or something?

MR. GALLAGHER: Yes, there wouldn't have been any areas of interest that needed to be interrogated, so it was more on the thicker side. And you can see, like some of the points that were interrogated, I mean, there's even a 940, you know, so it looked a thin spot relative to the rest of the area and so it was interrogated. So what we're saying is in that area there wasn't much area of --

MEMBER BANERJEE: So the thinned area would not be an elliptical area which encompassed 712, 736, 728, and to the right hand side 721? I mean, it doesn't have to be a circle.

MR. GALLAGHER: Right.

MEMBER BANERJEE: Just an ellipse.

MR. GALLAGHER: That could have been an approach, and that would have been, you know, a much exaggerated area. I mean, a 51-inch circle is a pretty big section of the sandbed.

MEMBER BANERJEE: Right. It doesn't have to be a circle. That's all I'm saying.

MR. GALLAGHER: It does not. That's right.

MEMBER BANERJEE: Right.

MR. GALLAGHER: But for modeling these we chose circles. And in our previous evaluations we did for, you know, CLB, current licensing basis, we used squares. So if you recall the discussion about a square, you know, it looks like a tray. There's a 12-inch square that comes down to a three-by-three-inch tray, so it almost, you know, looks like a tray. All we simply did was -- okay, this area was evaluated with a tray, and it was a three-foot-by-three-foot tray. So the hypotenuse of a three-by-foot is 51 inches.

MEMBER BANERJEE: Yes.

MR. GALLAGHER: So we just simply drew a circle around the entire thing and said we'll include that as a locally-thinned area. You know, it's important to note that the thickness in between these points are thicker than the points that are identified, because again these are points that are thin initially and then they were ground down to have an area to measure. So assigning it the entire area, you know, we think is a conservative input.

MEMBER SIEBER: Now the corrosion itself is a pitting-type corrosion as opposed to generalized corrosion, right?

MR. GALLAGHER: Well, it was general corrosion, but when you look at the pictures, you know, it's --

MEMBER SIEBER: Undulating?

MR. GALLAGHER: -- pock-marked or, you know, however you would describe it.

MEMBER SIEBER: Well, would you call it pitting-type or general?

MR. GALLAGHER: It's general corrosion.

MEMBER SIEBER: Okay. And your selection of points was based on judgment as opposed to a specific criteria?

MR. GALLAGHER: These external points?

MEMBER SIEBER: Yes.

MR. GALLAGHER: Yes. It was based on visual judgment, yes.

MEMBER BANERJEE: Do you have an idea of what the pH was in the water in the sandbed?

MR. GALLAGHER: There was some data on that.

Do we have that, Pete, the pH of the water.

MR. TAMBURRO: I'll check on the pH.

MR. GALLAGHER: Yes, we can get that. That was one thing we did present, because there was some data taken. And we'll see if we can --

MEMBER SIEBER: (Off microphone.)

MEMBER BANERJEE: Okay. So the area between 728 and -- sorry. Go ahead.

MR. GALLAGHER: Mr. Sieber?

MEMBER SIEBER: The water wasn't borated or treated in any way. It was just regular --

MR. GALLAGHER: Right, it was just condensate water, you know, clean reactor water and --

MEMBER SIEBER: But it would probably be close to seven in pH?

MR. GALLAGHER: Yes, but we did take that data and, you know --

MEMBER BANERJEE: So between the 728 point and the 721 point, were there any measurements showing thicker than that?

MR. GALLAGHER: They all would have been thicker. There were no points of interrogation, so visually --

MEMBER BANERJEE: Usually they look thicker. So the 721 area was slightly pitted or whatever.

MR. GALLAGHER: Right.

MEMBER BANERJEE: Or corroded. The 728, all the around the 728, 736, 712, there was a patch of corrosion sort of undulating but a large patch. That's why you modeled that based really on the visuals.

MR. O'ROURKE: Based on the visuals, that's correct.

MEMBER BANERJEE: Okay.

MEMBER ABDEL-KHALIK: I'm trying to figure out the reference point for the vertical access on this graph. Is there a physical point in which zero refers to?

MR. GALLAGHER: Yes, and it's actually different on each sandbed because sometimes it's right at the bottom of the reinforcement of the vent header, sometimes it's a weld that's kind of up along the side, you know, a weld line. So, you know, we have them marked for each sandbed. So these are trying to show, you know, generally where those particular areas are.

MR. O'ROURKE: A readily identifiable reference point that they could measure both horizontally and vertically to locate the point, the external point.

MR. GALLAGHER: A weld or the reinforcement of the vent header.

MEMBER ABDEL-KHALIK: The underlying reason for my question was, is there any physical reason why the vertical extent of that thinned area would be limited?

MR. GALLAGHER: Well, because the sand only went up to a certain elevation is one reason. And under the vent headers, you know, the sand actually moved down like this, you know? So maybe we can put slide 12 back up. Is that the bottom?

So if you look at the vent --

MEMBER ABDEL-KHALIK: Just Bay 19? Just the same --

MR. GALLAGHER: Yes, Bay 19.

MEMBER ABDEL-KHALIK: Right. Right here.

MR. GALLAGHER: So like that reinforcer at the vent header --

MEMBER ABDEL-KHALIK: Right.

MR. GALLAGHER: Okay. So the sand level, you know, would have been say in the blue area. And, you know, it's not going to be perfectly level. And so that comes around like that and then it would have been under the vent header itself and then, you know, in the blue area to the top of it. So, I don't know if I'm getting to your question. So the corrosion would obviously have stopped. You know, it would have only been where the sand was primarily.

MEMBER ABDEL-KHALIK: I'm just trying to understand. You know, you come up with a circle that's 5x-inches in diameter, whether this is sort of an eyeballing exercise or there's a physical reason why the size of that particular area is limited.

MR. GALLAGHER: Yes. There's evaluated areas that were based on this tray, and the tray is based on a local sensitivity. You know, so you could have thin areas less than 736 mils, which was the uniform thickness calculation that was done in the drywell, in the sandbed region. So if you can imagine, there's a general uniform thickness. If a point is above 736 mils in our licensing basis, it's okay. If it's below there, then we have a further evaluation. That further evaluation was based on a sensitivity that was done on the sandbed. And basically it says you could have this tray, a tray in each --

MEMBER ABDEL-KHALIK: My question is a lot simpler than that.

MR. GALLAGHER: Okay.

MEMBER ABDEL-KHALIK: Okay. I'm trying to understand the process by which you drew these circles.

MR. GALLAGHER: Right. So what I'm trying to say is we had these evaluated areas. Let me just simplify it then, because I was going into a long-winded discussion. Sorry about that.

MEMBER ABDEL-KHALIK: No, no problem.

MR. GALLAGHER: There was evaluated

areas that were done. So they would have been areas where there were some points that were less than 736 mils measure. And they were evaluated as these trays. And all we did is simply say let's just say the entire tray is that thin, very thin. And then for modeling simplification, we said, well, let's make it a circle. And so we encircled the entire tray and assigned it the same thickness. So that's why in the five bays we had five evaluated areas previously and we conservatively assigned a value based on data points within that and then enveloped the entire area with the circle rather than a square or a tray. And that's what we did.

MR. O'ROURKE: And as Francis mentioned, all of those changes in thicknesses are step changes. So you can imagine if you use a square, you artificially induce a stress point at the edges of the square. So the circles are more efficient for modeling.

CHAIRMAN SHACK: Yes, but that only pushes the problem back as to why you picked the rectangle in the original analysis. The circle bounds the rectangle, but --

MEMBER BANERJEE: I guess that was my question, that looking at the data some of it looks like -- I don't know what the visuals look like, but it looks like you are really talking about rectangles. You know, it looks as if there was a larger horizontal extent sometimes, not only in Bay 19, but if you look also at say the data in, let's say Bay 13, it seems that you could draw a rectangle around 602, 704, 669, 759, 739, so it would be sort of more horizontal. And I'm just wondering if you look at Bay 15, it's the same; 711, 777, 715, 760, 720, whether a square was really the way to bound this, or as Bill said, a rectangle and then put an ellipse around that rectangle if you want to get rid of the edges rather than a circle.

So I think you're going to have to answer that question, that the circle is more conservative than an ellipse from a buckling viewpoint.

MR. GALLAGHER: Well, I think that when you see the sensitivity results, you can see that, you know, the changes are pretty small for every bay-wide changes. So that's what we're trying to show.

And the other thing I think, you know, I mean, I --

MEMBER BANERJEE: It may be answered by

the sensitivity analysis, yes.

MR. GALLAGHER: Yes, I think sensitivity does. But agree with you, there's many ways that this could have been done. We tried to --

MEMBER BANERJEE: You could model it in different ways.

MR. GALLAGHER: Yes.

MEMBER BANERJEE: Yes.

MR. GALLAGHER: We tried to maintain some consistency with the CLB in evaluating these areas. But you're right, we could say, hey, let's draw and oval around here and that type of thing. And so --

MEMBER BANERJEE: It's in the eye of the beholder in this case.

MR. GALLAGHER: And we do have bay-wide sensitivity. And the other thing is I think, you know, you could almost view this relative to, you know, what's there as a sensitivity -- not a sensitivity, but, you know, we basically said rather than, you know, modeling say individual points or like smaller areas of thinness, we took a rather large area and conservatively assigned it, you know, a thin value based on the data we had, but conservatively based on the data we had. So there's more --

MEMBER BANERJEE: So let me ask a first order question from a buckling view point. Is it simply the amount of thinned area that you have locally that matters, or does its shape matter as well?

MR. GALLAGHER: Maybe we can have -- Stan, could you answer that?

MEMBER BANERJEE: I mean, at an extreme, if I took some area and I made it a circle or I pulled it in some direction, which is more conservative?

MR. TANG: I don't know the answer to that question off the top of my head.

MR. GALLAGHER: But now we do have various -- we have a 51-inch circle and an 18-inch circle.

MR. TANG: Right. Right, we did a sensitive study by changing the local area and the general area. But I haven't done anything that is looking at square, ellipse, or --

MEMBER BANERJEE: Well, a square is unrealistic clearly, because you have high stress concentrations at the edges.

MR. TANG: Yes, so I don't know that.

CHAIRMAN SHACK: As a scientific wild-ass guess, I mean, I would guess that making the thing thinner this way in the direction of your compressed stress is more limiting than making it wider. And, you know, if the buckling direction is this way, I want to get the buckling length as short as possible. So I would think a rectangle would be --

MEMBER BANERJEE: A horizontal rectangle would be better than --

CHAIRMAN SHACK: Beneficial compared to having the large --

MEMBER BANERJEE: -- vertical rectangle.

MR. TANG: I agree.

CHAIRMAN SHACK: But that's --

MR. GALLAGHER: Well, the other things that we should note and we didn't so far is most of these thinned areas are -- as a matter of fact, let me just take a look at that slide 12. Yes, most, if not all of the thinned areas are actually under the vent headers. And that's the stiffest part of the sandbed. You know, in between the vent headers is less stiff. So the corrosion where the sand and the water, you know, laid, was basically under the vent header and that's the stiffest part. So, you know, there's some strength there in the fact that that's where these thinned areas are and the other areas are in the areas that, you know, have less stiffness. So that provides you some, you know, saying that whether you make it circles or a rectangle, or, you know, this or that, it's all under the stiff location of the vent header.

MEMBER BANERJEE: That's a good thought. Thank you.

MR. O'ROURKE: All right. Moving onto slide 27. This is the Bay 1 locally-thinned area. We modeled a 51-inch circle that encompassed a large number of external measurement points. However, for conservatism we averaged just the four thinnest points shown in red. On here that averages 696 mils. We used that average for the entire circle. And you can see in the circle that the rest of the data points are all above 696. But again, conservative, 696 for the entire circle.

MEMBER ARMIJO: Would you just happen to know what the average is in that circle is if you averaged all the points?

MR. GALLAGHER: Yes, I think it's 800. It's like 799 or 800, Dr. Armijo. I did that, but I didn't write it down.

MEMBER ARMIJO: All right.

MR. O'ROURKE: I'll defer to the boss on that question.

MEMBER ARMIJO: Just rough numbers.

MR. O'ROURKE: On slide 28, for Bay 13 we modeled an 18-inch circle and we used the average of the three thin points within the circle sa the thickness of the entire circle, which is 658 mils. And you do note a point in there of 886 mils that we did not include in the average for conservatism.

CHAIRMAN SHACK: We could slide the circle over to accommodate --

MR. O'ROURKE: Again, the circles is in the area location of the previously evaluated area. So to be consistent, you know, we've located the circles over those areas, yes.

Slide 29. For Bay 15 we modeled an 18-inch circle and we used a value of the thinnest point in the circle as the thickness of the entire circle, which is 711 mils. So there's no average there. That's just one point. We used that point for the entire circle.

And finally, in Bay 17. In this bay we had previously evaluated two areas of interest as a locally-thinned area within a locally-thinned area.

The inner areas models an 18-inch circle. And we used a value of the thin point in that circle as the thickness of the entire 18-inch circle, which is 663 mils. The outer circle we modeled as a 51-inch circle with a thickness equal to the average of the five external points encompassed by the circle, which is 850 mils.

That concludes the discussion about the locally-thinned points. If there are no questions, I'll move on.

MEMBER ABDEL-KHALIK: In the selection of these circles, was there any consideration given to how far off center from the vents, the span between vents?

MR. O'ROURKE: No, we modeled the circles, as I said, in the locations of areas that we previously evaluated. So they fell where they fell.

MR. GALLAGHER: And they were all, you know, generally under the vent headers. I mean, you can see on the slide.

MEMBER ABDEL-KHALIK: Right. But of course, you know, the closer they are to the center between vents, the worse the situation would be from a buckling standpoint.

MR. O'ROURKE: Right. But that's where the data points were that we measured.

MR. GALLAGHER: Yes, so when you look at the external data points that were taken, you know, most of them were under the vent header, which means that they had the most degradation. There were very few points as you went out within each bay. So, you know, the way the sand was and the water, you know, there was more degradation, more thinning under the vent headers. Which fortuitously is good because it's the stiffest point, too.

MEMBER ABDEL-KHALIK: Okay. Thank you.

MR. O'ROURKE: Okay. Slide 31.

MEMBER BANERJEE: And that's why I guess the shape matters less because --

MR. GALLAGHER: It's under that stiff area.

MEMBER BANERJEE: Right.

MR. O'ROURKE: So all of my previous discussions were based on the thickness measurements that were taken during the 2006 refueling outage, October 2006. In order to meet the proposed license commitment to perform the 3-D analysis, we began this project in early 2007. The 2006 measurements were the latest available data at the start of the project. However, we did repeat the measurements in 2008 and verified that the 2008 data not only met the acceptance criteria, but that it also compared favorably with the 2006 data. And as you can see from bullet 2, where we compared the measurements, there were no significant deviations, variations in the measurements. So we therefore concluded that the 2006 measurements remained an acceptable representation of the drywell shell thicknesses. And that's what the 3-D analysis is based on.

At this point we're ready to get into the finite element modeling, so keep going, Dr. Shack?

CHAIRMAN SHACK: Yes, I think we'll keep going for another 20 minutes. We have to be out of here at 11:00.

MR. O'ROURKE: Okay. Very good.

And then at this point I'll turn the presentation over to Francis Ku from Structural Integrity Associates who will discuss that model.

MR. KU: Thank you, John. Again I'm Francis from Structural Integrity Associates and I'll be presenting the 3-D finite element model used in the Oyster Creek drywell analysis. From here on I will call it as the model within this section.

First, I would like to start from slide No. 33. I'll start with the ANSYS versions that were used in the analysis.

We used to versions. Version 8.1 was used to create the model and version 11, when it became available, was used to actually match the model and perform the finite element analyses.

ANSYS is an industry accepted finite element analysis software package. The model was created using area entities in 3-D space at the mean thickness location of the shell thickness. The model was also created using the dimensions and material properties from the OEM design inputs.

The 3-D model accounts for the asymmetric behavior of the model and all of the major components are modeled and they will be elaborated in more details in the subsequent slides within this section.

CHAIRMAN SHACK: This is all basically linear small deflection shell theory we're talking about here?

MR. KU: Right. All in the elastic small displacement and small string analysis.

MEMBER BANERJEE: And you said ANSYS was used. Is that because you use ANSYS? I mean, I saw in Hutchinson's note sort of a reference to ABAQUS, which I'm sort of more -- so why did you choose --

MR. KU: Because in our experience, I mean, ANSYS is widely used in the nuclear industry, so we feel more comfortable to use ANSYS for this analysis. That's the reason.

CHAIRMAN SHACK: The Sandia people used ABAQUS, I think.

MEMBER BANERJEE: ABAQUS, right?

MR. KU: Yes, they did.

So the bottom portion of the slide includes all the major modeled components. I'll go over them briefly. It includes the top head assembly, including the closure flange, the cylindrical shell, the shell knuckle and the spherical shell regions. It also includes the vent pipe assemblies with the attached vent headers and downcomers for boundary condition stiffness purpose. All of the prescribed 208 penetrations are also modeled, as well as the stabilizer assemblies within the cylindrical shell portion. They are part of the star truss assemblies. Also modeled are the weld pads and the beam supports. Finally, the bottom head is also modeled.

MEMBER ABDEL-KHALIK: Back to the

question I raised earlier about the boundary condition as far as the end of the model for the vent lines.

Does the model assume that the load is transmitted uniformly to all vent lines?

MR. KU: Yes.

MEMBER ABDEL-KHALIK: Now how do we know that that's true?

MR. KU: No, it's not really uniformly, because we actually modeled the vent lines and we put the realistic boundary conditions on the vent lines. So whatever load was transferred into the vent lines, it will be accounted for.

MEMBER ABDEL-KHALIK: But I'm talking about the real world now, okay, rather than the model. How do we know that the load is uniformly transmitted to all vent lines?

MR. GALLAGHER: Well, I guess you were saying it's not uniform, because the containment is not actually, you know, perfectly symmetric and Francis will go into that.

MR. KU: And the loads is also not perfectly symmetrical. So that's the purpose of the 3-D model.

MR. GALLAGHER: And so I think he

corrected himself, Dr. Khalik.

I think, Francis, you said that it's not uniformly distributed, is that correct, to the supports?

MR. KU: Right.

MR. GALLAGHER: It would be whatever gets transmitted down that vent downcomer to its support. So each support could be different. It's whatever was transmitted to it.

MEMBER ABDEL-KHALIK: I guess the question in my mind is if for some reason one of these vents lines is cantilevered and doesn't transmit load, is that a sort of more demanding situation? So the assumption that all vent lines are transmitting load to the torus, would that really be a conservative or a non-conservative assumption?

MR. KU: For the purpose of the analysis, we just assumed all the vent line connections to the torus are intact. They're all perfectly --

MR. GALLAGHER: The design drawings were used to say, you know, what are the attachments and so that was what was modeled. So, you know, assuming the attachments are there, then the load would be transmitted based on --

MEMBER ABDEL-KHALIK: And those attachments are indeed intact, all of them?

MR. GALLAGHER: They are installed per the design drawings.

MEMBER ABDEL-KHALIK: Okay. All right. Thank you.

MEMBER SIEBER: Could you tell me on slide 7 where the star truss is located? Or is it on there?

MR. KU: It's somewhere in the middle of the shell region. So it's on the top of the --

MR. O'ROURKE: It's on the top of the shell.

MR. KU: Right. It's right on the top of the reactor biological shield. That's where the star truss is.

MR. GALLAGHER: Yes, on slide 34 is where they're shown, Mr. Sieber, if you want to -- right? The green?

MR. KU: Right here. All these green circles with the red.

MR. GALLAGHER: Slide 34.

MEMBER SIEBER: Yes, I got it.

MR. KU: It goes in the --

MR. GALLAGHER: So the green circles are --

MEMBER SIEBER: Oh, okay. Thanks.

MR. KU: So let's move onto to slide 34 then, since we're on it.

So this is an overview of the outside of the drywell model.

MEMBER BANERJEE: Do those boundaries show the size of your mesh?

MR. KU: No, this just an overview of the model.

MEMBER BANERJEE: Okay.

MR. KU: We show the mesh details in the later on slides.

MEMBER BANERJEE: So when you have that green bit, say, and you have the lines, what do those lines mean?

MR. KU: Those are the area entities used to build the finite element model.

MEMBER BANERJEE: So within those lines and the green bit you have a mesh, right?

MR. KU: Yes, right.

MR. GALLAGHER: Yes, Dr. Banerjee, if you look on slide 48 --

MEMBER BANERJEE: Okay.

MR. GALLAGHER: -- that's basically the same drawing, but it's trying to show all the mesh sizes. And you can see it looks pretty black because, you know, the mesh sizes are small.

MEMBER BANERJEE: Right. Okay. Yes.

MR. KU: I'll talk about that, you know, as we go.

Okay. Let's continue on with slide 34. And as you can see from the model, eight colors were used to illustrate the various shell thicknesses assigned to the areas. The colors are only for visualization purposes, because only eight colors are used, while there are many different shell thicknesses. So some areas with the same color may be of different shell thicknesses.

The figure also shows the equipment access hole or the hatch extruding out from the lower right portion of the spherical shell.

MEMBER ABDEL-KHALIK: And which bay does that correspond to approximately?

MR. KU: It's between Bay 1 and Bay 19.

MEMBER ABDEL-KHALIK: Okay.

MR. KU: It's the hatch. Right in the middle of the Bay 1 and Bay 19.

MR. GALLAGHER: I think you can see that

on the slide 12.

MR. KU: Yes, slide 12 it shows it.

MR. GALLAGHER: So in the southeast quadrant of that you can see the -- yes, that's it.

MR. KU: Lower left portion of the figure.

MEMBER BANERJEE: And the blue things at the bottom, are they these --

MR. KU: Those are the vent headers.

MEMBER BANERJEE: Okay. How is the whole thing supported again, going back to Said's question?

MR. KU: Yes, if you look at the design drawings, they are at this flange locations on the vent headers. They have vertical beams connected these flange to the toruses. That's where we put the vertical boundary conditions on these flange locations.

MEMBER BANERJEE: Where are the flanges? At the end of the vent headers?

MR. KU: It's near each end of the vent header. You have this little flange to provide additional stiffness to the vent header. And at the bottom of the flange there's some vertical beams connect the flange to the torus. And that's where the vertical boundary conditions were applied.

MEMBER BANERJEE: And the torus sits within a concrete shell or something? The top of the shell?

MR. GALLAGHER: Yes, there's a saddle. There are saddles anchored to the concrete.

MEMBER BANERJEE: Okay. It just sits on concrete?

MR. KU: Okay. If there's no more questions, I would like to move forward to 35.

Figure 35 shows the sectional view of the top header and the closure flange assembly. The circles on the elliptical shell, these green and blue circles on the elliptical dome actually represent the access hole plate that were modeled.

The insert on the figure on the lower right corner of the figure shows the reinforcing plate near the flange, at the flange connection.

Thirty-six. Next slide. This figure represents the sectional view of the upper portion of the model. It also shows the modeled components inside the upper portion of the model. It shows the connection between the top head, the cylindrical shell and the shell knuckle region. It shows how they are connected and a little bit of a view of the interior components that are modeled.

Next slide.

MR. WILKOWSKI: Are those like the main steam line and feed water line penetrations?

MR. KU: I can't recall those penetration. We have 208 of them.

MR. GALLAGHER: Yes, they would be modeled in there.

MR. KU: Yes, if they are more than three inches in diameter, they would be modeled.

We're on 37. Is similar view to the previous slide, but it has a more zooming view of the internally modeled components. Just give you an example of it is the green, the light green is the latches on the lower closure flange and the red and the light blue color are the two modeled large-diameter penetrations in the cylindrical shell region. And these purple cylinders right next to them are the small-diameter penetrations that are modeled. Also modeled are all of the stiffening rings on the inside of the cylindrical shell, the blue color on top and the two purple colors in between on the top and bottom ends of the star truss assembly.

Move onto slide No. 38. This figure

shows the isolation view of the star truss assembly them self. So they are total number of 10. One, two, three, four -- no, I'm sorry. That's a total number of eight star truss assembly modeled. The boundary conditions applied on this assembly are on the outside of the assembly. On the outside of the reinforcement plate, there are those metal locks. They actually anchor onto the red-tipped building wall. So the circumferential movements on all these metal locks are constrained. That's the boundary condition applied on the star truss so they cannot rotate. Right, they can't expand radially.

MEMBER ABDEL-KHALIK: But is that really true?

MR. KU: Yes.

MEMBER ABDEL-KHALIK: There is no tangential degree of freedom in this case, in the way the supports are held in place?

MR. KU: Yes. Those are more like slot fittings onto the mating slots.

MEMBER ABDEL-KHALIK: Okay.

MR. KU: So there's no really tangential movements.

MR. TANG: Actually, the star truss has a plate coming out and fit into the slot in the reactor buildings. And actually there's a gap in there, but the gap is very, very small.

MEMBER ABDEL-KHALIK: Okay.

MR. TANG: Yes, in terms of mils.

MR. KU: Those are one inches, yes.

MR. TANG: Yes. So you know how somes when you stack, you know, that would be low tangential movements since essentially the reactor building walls would limit -- restrict, you know, the circumferential displacements.

MEMBER ABDEL-KHALIK: Okay.

MR. TANG: That's how we modeled the boundary condition on the star truss.

MEMBER ABDEL-KHALIK: Okay. Thank you.

MR. KU: I would like to move on to next slide.

The figure in this slide shows the shell knuckle region between the cylindrical and the spherical portion of the shell. The insert figure on the upper left corner, the blue circle represents the welding pads. They are modeled on the lower portion of the knuckle region.

MEMBER BANERJEE: So do you know the thickness of that welding patch?

MR. KU: Yes, they are provided from the

OEM.

MEMBER BANERJEE: But this is thicker piece than the cylindrical --

MR. KU: Yes. Yes.

Move onto slide No. 40. Figure 4.9 in this slide represents the isometric view of the model. It excludes the upper portion of the model to give you an inside view looking down into the spherical region of the shell. You can see the access hatch again extruding outside.

Next slide. Figure 4.10 is the same isometric view as the previous one, but it provides a sectional view of the spherical shell to give you more viewing details on the model components on the inside of the model. To put this figure into perspective, if you look at the left side of the sectional view, that two circles below the vent pipe, and this is Bay No. 17. And right on the right of it, the green circle, Bay No. 1 -- actually, it's Bay No. 19, I'm sorry. It's Bay No. 19 and then followed by the blue circle in Bay No. 1. And then Bay 3 has no corrosions, no localized corrosions. And again, the hatch is in between Bay 1 and Bay 19.

In this figure there are two small

inserts, which are the zoom-in view of the modeled upper beam support. And the lower insert is the zoom-in view of the modeled lower beam seat and its reinforcement plate attaching to the spherical shell. And I also would like to note that the --

MEMBER BANERJEE: Come again about this reinforcement plate? What did you say about it?

MR. KU: Yes, if you look at the lower beam seat, they are not exactly weld directly onto the purple spherical shell. They actually weld onto the green reinforcement plate first. And then the plate is welded onto the shell.

MEMBER BANERJEE: Okay.

MR. KU: Another thing, on the supports they are not evenly spaced, as you can see from the figure over here. Some locations they spaced wider than the other locations. So that kind of provide the other non-symmetric-type of loading for the model also.

So let's move to the next figure on the next slide.

MEMBER BANERJEE: What are those little red things there? They're just pipes or what?

MR. KU: What little red --

MEMBER BANERJEE: In the -- above, let's

say, one of the vent holes and --

MR. KU: Oh, these are the penetration. Are you talking about these?

MEMBER BANERJEE: Yes.

MR. KU: Yes, these are some of the modeled penetrations.

MEMBER BANERJEE: They're little pipes, basically?

MR. KU: Yes. Yes.

This is the same sectional view as the as the previous slide, but it's looking at the elevation view. So it shows the modeled welding pad on the upper portion of the shell and the flange, the modeled flange at the end of the vent pipes.

If there's no question, I'll move to 43, slide 43.

Figure 4-17 in this slide shows the detailed of the modeled vent pipe assemblies. There are a total of 10 of those modeled. They are evenly spaced around the circumference of the lower spherical shell region. The vent pipe assembly includes the flow deflector plate assemblies on the inside of the spherical shell, so they are all modeled.

MEMBER ABDEL-KHALIK: I was trying to

figure out how the boundary condition is applied to this. Is there anything beyond this that's included in the model? Is there any physical component that's included in the model beyond this?

MR. GALLAGHER: For the vent headers?

MEMBER ABDEL-KHALIK: Right.

MR. KU: Right. Yes, I mean, there's the vent header connecting to the end of the vent pipe.

MEMBER ABDEL-KHALIK: Right.

MR. KU: They are isolated, you know, for the purpose of showing the vent pipe assembly only.

MEMBER ABDEL-KHALIK: Right.

MR. KU: But in the actual model --

MEMBER ABDEL-KHALIK: You actually include the actual --

MR. KU: Yes, actually include --

MEMBER ABDEL-KHALIK: And the supports?

MR. KU: And the supports.

MR. GALLAGHER: Yes, so the model -- that was the first slide?

MEMBER ABDEL-KHALIK: Right.

CHAIRMAN SHACK: They're showing this portion of it now, but the rest of it's all there.

MEMBER ABDEL-KHALIK: Right. Now, you have indicated that you have good confidence that the load is being transmitted to all supports. How frequently are those supports inspected?

MR. GALLAGHER: Well, I mean, the torus is accessed every outage.

MEMBER ABDEL-KHALIK: Is that part of that in-service inspection that these particular supports are inspected?

MR. GALLAGHER: Pete, do we have any --

MR. TAMBURRO: This is Pete Tamburro. We do structural monitoring of the torus room and these supports would be a part of that tour, as part of the ASME IWE program.

MEMBER ABDEL-KHALIK: Okay.

MR. KU: All right. Now let's move on to slide 44 then.

MEMBER BANERJEE: This is a visual sort of inspection of the supports? When you tour at every outage, do you just look at the supports, or what do you do?

MR. TAMBURRO: The supports are looked at as part of our structural monitoring program where a structural engineer performs a fairly rigorous walkdown with checklists and he's looking for degradation such as corrosion, bolts and nuts that are separated, that type of an indication of degradation.

MEMBER BANERJEE: Did you find any degradation in the supports?

MR. TAMBURRO: None significant that hit my memory, no.

MEMBER BANERJEE: Okay.

MR. GALLAGHER: And, you know, if there was anything --

MEMBER BANERJEE: You would fix it?

MR. GALLAGHER: Yes, it gets entered into a corrective action program and corrective action is one of the elements of our aging management program.

MR. TANG: May I add one point? Actually, the modeling of the vent headers and the vent pipes is just to provide a boundary stiffness to the models. We are not really looking at the structural stresses on the vent pipes or vent headers, or anything inside the torus or the torus. So essentially it's just to provide -- we don't want to make assumption of the boundary stiffnesses on the vent pipes, so we go ahead and model the whole thing so that, you know, we have the actual stiffnesses.

MEMBER BANERJEE: So the boundary condition is no displacement at these points, is that it?

MR. TANG: There's no displacement.

MEMBER BANERJEE: Right.

MR. TANG: No, there's no displacements at the supporting point where there's columns connecting from the reinforcing plates in vent header to the bottom of the torus.

MEMBER BANERJEE: Right.

CHAIRMAN SHACK: Okay. We're going to have to break now for lunch. We will return at 12:30.

(Whereupon, the meeting was recessed at 11:00 a.m. to reconvene at 12:30 p.m. this same day.)

A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

2:29 p.m.

CHAIR SHACK: Let's go back in session, please. Dr. Ku, you have the floor.

MR. KU: Okay. Good afternoon, everyone. Again, my name is Francis Ku from Structural Integrity. I'll be continuing the Oyster Creek 3-D Drywell Finite Element Model portion of the presentation starting from Slide 44.

This is the -- the figure in slide 44 is the elevation view of the lower spherical shell region. The red band color striping figure shows the sandbed region. And below the sandbed region is the embedded region.

MEMBER ABDEL-KHALIK: Just for calibration to follow-up on our earlier questions regarding the boundary conditions --

MR. KU: Um-hum.

MEMBER ABDEL-KHALIK: -- how much of the total load is transmitted to the concrete in the embedded region versus the load that is transmitted through the support for the vent lines?

MR. KU: We cannot look into the reaction loads in detail, so I --

MEMBER ABDEL-KHALIK: Do you have any sort of idea about, you know, is it 50 percent? Is it 10 percent?

MR. KU: It depends on the type of loads, because we put many different types of loads into the model. And we analyzed them individually. So it depends on what type of loads you are talking about. If you are -- let's say, for example, for horizontal seismic movement loads, I wouldn't expect much loads being transferred into the sandbed region. But if you're talking about pressure --

MEMBER ABDEL-KHALIK: The vertically-oriented --

MR. KU: The vertical load --

MEMBER ABDEL-KHALIK: -- load?

MR. KU: -- it will be like the majority of the loads will go directly.

CHAIR SHACK: Yeah, I guess, those are relatively flexible.

MR. KU: Right.

CHAIR SHACK: So they will just bend in the base.

MR. KU: Yeah.

CHAIR SHACK: For vertical loads it will go right to the concrete.

MR. KU: Yeah.

CHAIR SHACK: Because the other ones are so flexible that I'll just --

MR. GALLAGHER: Yeah, Stan, do you have any --

MR. TANG: Yeah. It is all depending on what kind of load that you apply. Remember that we have a boundary condition at the star-truss and the boundary conditions in the embedded concrete and remember the one header and the -- part of the downcomer only for stiffness, okay, in the phase with the drywells.

So if the load is applied at a top percent, most of the load will go into the star-truss boundary conditions.

MEMBER ABDEL-KHALIK: Will go where? I'm sorry. Say that again.

CHAIR SHACK: Star-truss.

MEMBER ABDEL-KHALIK: Oh, I see.

MR. TANG: A star-truss, you know, because we have a boundary condition in there. So if the loads are applied mostly at the top of the cylinder, then the majority of the reaction would go into the star-truss boundary conditions. And some of those loads also would transmit onto the, most likely would be, embedded concrete regions.

CHAIR SHACK: Okay. All right. Thank you.

MR. KU: Let's continue on 44. I want to elaborate a little bit on 44. I want to elaborate a little bit more on the boundary conditions. We applied on the embedded region below the sandbed region, we applied only radial constraints. So we kind of neglect the friction between the concrete and the steel, so we only have radial constraints.

And next slide. The two figures in this slide shows the details of the modeled -- some of the modeled penetrations. And there are two types of penetration reinforcing, two types of penetration reinforcement configurations. The figure up to the left, Figure 415.

MEMBER ABDEL-KHALIK: Sorry. Back to the statement you made earlier.

MR. KU: Um-hum.

MEMBER ABDEL-KHALIK: Um, is it just because you didn't know how to apply the tangential boundary condition or is it because --

MR. KU: Because --

MEMBER ABDEL-KHALIK: -- it is insignificant?

MR. KU: -- we don't really know the

friction between the concrete and the steel shell. And we thought it was more conservative to leave it.

MEMBER ABDEL-KHALIK: Is it really conservative if you allow it to slide?

MR. KU: A little bit, yeah. You will provide more length for stresses and you allow more displacement of the drywell, so it would expand also due to thermal loads. Due to pressure and thermal loads, you allow, you know, expansion.

MEMBER ABDEL-KHALIK: Less constraint?

MR. KU: Less constraint.

MEMBER ABDEL-KHALIK: So those stresses get lower. He's arguing for buckling rather than --

CHAIR SHACK: Right. That's the point for buckling.

MEMBER ABDEL-KHALIK: -- for stress.

CHAIR SHACK: For buckling, I'm not sure it would be more conservative. Would it?

MR. KU: It is more conservative.

CHAIR SHACK: I'll have to think about that --

MEMBER ABDEL-KHALIK: It's less constrained.

CHAIR SHACK: -- intuitively.

MR. GALLAGHER: Do you have anything to

add?

MR. TANG: Actually, the boundary condition at the embedded region, we constrain in the radial directions. The explanation is that in the radial directions, we know that the concrete, embedded concrete would provide constraint in the radial directions, because if you've got -- I'm just taking average from.

MEMBER ABDEL-KHALIK: Yeah, right.

MR. TANG: And then on the circumferential directions. Okay. There may be some sliding effect depending on how good the bonding is between the concrete and the drywell. So we did not put any constraint direction in the circumferential directions. Okay. Now, but you look at the radial directions, actually everything composed into vertical directions and the horizontal directions, it does provide some constrains in the vertical direction, but may not be as, you know, a vertical one.

MR. WILKOWSKI: How about the skirt location? How about the skirt location? Because that's -- a skirt is welded there and so you're just doing the -- not allowing that to be pinned?

MR. KU: The skirt, yeah. That's -- the skirt were actually pinned and circumferential also.

MR. WILKOWSKI: Okay.

MR. KU: So it won't rotate.

MR. WILKOWSKI: Right.

MR. KU: Yeah. That's the thing.

MR. WILKOWSKI: Yeah. Thanks.

MEMBER ABDEL-KHALIK: Okay.

MR. GALLAGHER: Okay, Francis.

MR. KU: Let's move on to Slide No. 45. I talk about the two types of penetration reinforcements. The figure to the left, Figure 415, is the penetrations with insert plates. You have actually -- actually, a hole was cut through the sides of the insert plate and the insert plate was welded directly to the shell.

And the second type is shown in Figure 414. This is the type of penetrations with a reinforcing plate. So they are additional -- there is an additional circular plate weld on the surface of the shell. These are two types of reinforcements remodeled.

Next slide, please, 46. This table, Table 42 provides the nominal mesh size used to generate the finite element model. I would like to look at the regions or components with thinner wall thicknesses assigned smaller mesh sizes. For example, the local thinning area we used a very small size of .75 inches square and the sandbed region also was on a small size 1.5 inches square.

CHAIR SHACK: Now, the local thinning, did you put in a transition thing or that's also just a step change?

MR. KU: It's a step change. We did not do any transitions.

Next slide, Slide No. 47. As I mentioned earlier before the break, the finite element mesh was generated directly or say internally using ANSYS. We did not use any third-party mesh software, so we just meshed the model directly in ANSYS.

The elements that were used to generate the mesh for drywell model is follow linear elastic Shell63 elements in ANSYS. The resulting model includes about 400,000 elements and nodes. And we did a mesh sensitivity study to validate the 400,000 mesh model.

In the sensitivity study, we created a finite mesh model that has about 1 million elements. Using -- it's based on this identical geometric configuration of the 400,000 model. It just meshed with more refinement.

CHAIR SHACK: Let me just ask you a

question about the analysis. When you -- I look at Table 8-3 and, you know, the first 10 modes have no displacement in any of these. And I'm trying to figure out what this means. You know, this is a linear Eigenvalue problem. I would expect to get an Eigenvalue and a mode shape. The amplitude of the mode shape would be indeterminant, but you have it as zero everywhere. And what do these modes represent? These zero-displacement modes.

MR. KU: Let me see.

CHAIR SHACK: Table 8-3 is one, the first 10 modes, everything is zero.

MR. KU: Okay.

CHAIR SHACK: Because --

MR. GALLAGHER: What page is that, Dr. Shack?

MR. KU: On the summary report?

CHAIR SHACK: Oh, hold on.

MR. GALLAGHER: Page 8-19?

MR. TANG: A-23? The table --

CHAIR SHACK: I mean, your report.

MR. GALLAGHER: Right.

CHAIR SHACK: And it's -- let me just -- it's Table 8-3 and it's page 8-19.

MR. KU: Oh, okay. These are the

buckling. These are buckling modes. Okay. I'm sorry, these are the buckling definition modes. Okay. Not the seismic.

CHAIR SHACK: Right, this is a buckling load.

MR. KU: Okay. Right.

MR. GALLAGHER: So he wants to know what the zero means.

MR. KU: Okay.

CHAIR SHACK: Right. What is a mode shape when everything is zero?

MR. TANG: No, no. Actually, there are some small amount of deformations. And also some times, you know, the deformation is significant in safer insert in the cylindrical portion of it. And then but --

CHAIR SHACK: Well, that's why I'm -- these first 10 modes are particularly -- you know, I can understand the case where you have got deformation in the cylinder and none in the sphere, that's okay, or deformation in the sphere and none in the cylinder, that's a buckling mode, one or the other. But the first 10 modes here, I've got nothing nowhere.

MR. KU: Let me try to clarify the tables. If you can see from the table, it only shows the modes on the regions that were reported. Namely, the spherical shell and sandbag region. But some of the modes actually happened somewhere else. They are not shown in the table.

CHAIR SHACK: Oh.

MR. KU: For the first few modes actually happen on the vent pipe, those vent headers rocking, so they are not reported in this table.

CHAIR SHACK: Okay. But why isn't the failure of one of those buckling failures a failure? Why do we go up to the modes in the sandbed or the cylinder before we call it a failure?

MR. KU: Because we did not include the vent header portion as part of this analysis. So we're only concerned about the sandbed region. So the model --

CHAIR SHACK: Okay.

MR. KU: -- the header --

CHAIR SHACK: The vent header, you don't really care for this particular --

MR. KU: Right, right.

CHAIR SHACK: Okay. Okay.

MR. KU: Right.

CHAIR SHACK: Let me think about that for a while. But next question, when you do the spherical shell analytically, you get this peculiar thing that you get multiple modes for each Eigenvalue. Does that show up as some kind of a slightly unstable result when you are doing the numerical case?

MR. O'ROURKE: Do you want to answer that, Stan?

MR. TANG: Actually, when we did the modal extraction for the buckling, we have some instability, but that is due to the numerical, so we have to start with a mode that is a little bit above zeros. If we don't specify the mode, you know, the program we're trying to extract the mode at, the rate of across mode which is essentially is not representative, it's essentially a numerical disability.

So we start the -- extracting the mode a little bit above the zero modes. And then go from there.

CHAIR SHACK: I'm not sure that answers my question, but that's okay. Let me see, just coming back to this vent header thing, wouldn't the code require me to have the same margin against buckling of the vent header that I had against buckling of the shell or is that -- or there is a different requirement?

MR. TANG: I think we are concentrating on the drywells. Even though there is a buckling mode, we did not do a stress analysis on the vent headers. So that's why we, essentially, don't consider those mode, even though the research continued the mode on the vent header. Remember, though the vent header and the downcomer and the -- as I mentioned before, it's only to including to provide the boundary stiffnesses and we are not looking into the stresses or buckling on those items.

We may as well put a stiffness matrix at the end of vent pipe and without, you know, including the modeling of the vent header and the vent pipe and the downcomer, but we thought that we do a better job to model those and to provide the stiffnesses.

CHAIR SHACK: Would the code require you to have those kind of margins for the vent header?

MR. GALLAGHER: Well, the code would be based on the piping code, right? But I guess, Dr. Shack, what we -- maybe we're not being clear about what we tried to do here.

The -- rather than just cut the model at the vent itself and apply a support, an artificial support, you know, beam or whatever, we tried to just do the whole structure. But we didn't do a detailed modeling of that vent header. So really, it really was just to have like a continuous -- so we could see if there was -- we could model the support, the boundary condition and try to mimic it as closely as we could.

But we didn't do a detailed study, so -- on the vent header. So when Francis is saying the mode shape could have been in that vent header, you know, we're not saying that it would have buckled there or whatever, because we didn't go through that detail analysis.

CHAIR SHACK: It has an Eigenvalue.

MEMBER BANERJEE: But it is fairly coarsely meshed, you're saying?

CHAIR SHACK: I mean, that's one argument. But then --

MR. GALLAGHER: We didn't model it in detail.

CHAIR SHACK: The question is does it signal that you need to go back and look at that, I guess? And maybe the staff will have some comments on that.

MEMBER ABDEL-KHALIK: But how do you define failure?

MR. GALLAGHER: I'm sorry.

MEMBER ABDEL-KHALIK: How do you define

buckling failure for this system?

MR. GALLAGHER: If it didn't meet the code minimum.

MEMBER ABDEL-KHALIK: Right. Where?

MR. TANG: The buckling mode shape would tell you where the buckling would occur.

MEMBER ABDEL-KHALIK: So based on what we heard, this were to include those vent pipes, wouldn't you have had to look at those?

MR. TANG: As I mentioned before, because the purpose is look at the drywell of this.

MR. GALLAGHER: We didn't model it in detail.

MR. TANG: Yeah.

MR. GALLAGHER: And that's what we're trying to say.

MEMBER ABDEL-KHALIK: But let's -- the purpose is to see whether this structure meets the code requirements, not whether a part of the structure meets the code requirements.

MR. GALLAGHER: Well, I mean, the only thing we can say is that those structures have not been affected, you know, by any degradation. They were part of the original design basis and were analyzed, you know, for that. So you know, we were just trying to model a boundary condition and then look at the area that has been changed and affected.

We had to cut it off some place and we thought we were doing --

MEMBER ABDEL-KHALIK: I understand where you cut it off.

MR. GALLAGHER: We thought we were doing a better job to rather than just provide artificial beam supports to basically, you know, do some mimic of the configuration and go from there. So we think, you know, the approach was pretty good.

MEMBER BANERJEE: How did you model the bellows? I'm interested in that.

MR. TANG: We did not model the bellows. But the bellows were --

MEMBER BANERJEE: What role do the bellows play here? I mean, do they sort of have enough -- do they sort of isolate things, so that there are two or more separates --

MR. TANG: That is certainly what the bellow is for. Because it's, essentially, so flexible that the loading from the vent pipe is not going to transmit onto the torus.

MEMBER BANERJEE: Right. So then it becomes an issue. I'm just trying to understand your models. So you've got supports on this ring, more or less, from which these downcomers come, right? And they are direct supports. And then between that and the spherical structure, there are bellows, right? So how does that support that? I mean, that's really the question I have. Do you follow what I'm saying?

Between the points that which you have your boundary condition set, zero-displacement boundary conditions, nodalized elastic structure, let's say, the bellows are there in between. So if you model the bellows, how is that boundary condition then being applied to the main structure, which is the spherical shell?

MR. TANG: But the boundary conditions going through the vent pipe --

MEMBER BANERJEE: Yes.

MR. TANG: -- and the downcomer.

MEMBER BANERJEE: Through the vent pipe, but the vent pipe has in between some bellows, right?

MR. TANG: Yeah, the bellow, essentially, is connecting from the vent pipe onto the torus.

MEMBER BANERJEE: Right. So now if you don't model the bellows, how is the boundary -- effect of the boundary condition transmitted?

MR. KU: Let me try to answer your

question. The bellow is not at -- is actually not connected to the downcomer. It's connected directly onto the torus. So we assumed the bellow is very flexible.

MEMBER BANERJEE: Yes.

MR. KU: So there is no load transmitter from the vent pipe to the torus, but the vent header is directly connected to the vent pipe.

MEMBER BANERJEE: Okay. So let's go back to that nice picture you showed with the concrete --

MR. GALLAGHER: Page 34, is it?

MEMBER BANERJEE: No, it was more --

MR. KU: Page 7.

MEMBER BANERJEE: Yeah, I think the --

MR. KU: Page 7 with the overall drawing?

MEMBER BANERJEE: Yeah, overall drawing. I'm trying to understand that.

MEMBER ABDEL-KHALIK: Don't you have to look at 34?

MR. GALLAGHER: That's what I thought.

MEMBER BANERJEE: We may have to, but let's start with 7. There you've got an expansion bellows which seems to be between the vent header and the 81 inch diameter vent there.

MR. KU: No, if you actually look at the

closer view of the OEM input, the original fabrication drawings, the bellow is connected onto the torus. It's not connected to the downcomer. It's fixed on the bellow and to the right of it you have another extension of it.

MEMBER BANERJEE: Yeah.

MR. KU: That's connected to the torus, not the vent pipe.

MEMBER BANERJEE: So the bellows is not part of that vent pipe leading from the --

MR. KU: No, no.

MEMBER BANERJEE: -- drywell to the thing?

MR. KU: No.

MEMBER BANERJEE: It's just external?

MR. KU: Yeah. It's externally connected to the --

MEMBER BANERJEE: External. So that's -- so it allows you --

MR. GALLAGHER: Like a sleeve.

MEMBER BANERJEE: -- to move. A sleeve?

MR. KU: Yeah. So your vent pipe, the downcomer move together.

MEMBER BANERJEE: So it's all --

MR. KU: It doesn't move.

MEMBER BANERJEE: Okay.

MR. KU: It doesn't move the torus.

MEMBER BANERJEE: That explains it.

MR. KU: Yeah.

MR. GALLAGHER: It maintains the pressure boundary of the torus.

MR. KU: Right.

MEMBER BANERJEE: Yeah, got it. Okay. It doesn't give you any flexibility.

MEMBER ABDEL-KHALIK: That's a reason.

MR. KU: Right.

MR. GALLAGHER: So did we answer your question?

MEMBER ABDEL-KHALIK: No, but --

MR. GALLAGHER: Okay.

MEMBER ABDEL-KHALIK: -- we will pursue it later with the staff.

MR. GALLAGHER: Okay.

MR. KU: I think we are on Slide No. 47, talking about the general mesh and sensitivity study. So let's continue. We did a -- we created a finite mesh element, finite element model containing about 1 million elements. We did that by reducing the mesh, the nominal mesh size specified in Table 4-2 by about half. So everything is reduced by half.

And then we test the refined model with

internal pressure loading. And we evaluate the stress intensity results.

MEMBER BANERJEE: What do you mean by an element and an node? Element is a mesh.

MR. KU: Element is the area and energy. Node is the corners of the element.

CHAIR SHACK: Where the corner -- the elements are connected.

MEMBER ABDEL-KHALIK: Okay.

MR. KU: So we looked at the difference between -- we looked at the difference in maximum and minimum stress intensity results between the 400,000 element model and the 1 million element model and --

MEMBER ABDEL-KHALIK: The difference because these are not necessarily quadrilateral elements.

MR. KU: Right. Some of them are actually triangular elements, yeah.

MEMBER ABDEL-KHALIK: It is on. But, yeah, okay.

MR. KU: All right. We look at stress intensity results between the two models. And the observation was that the difference between the 400,000 element model and the 1 million element model were really insignificant. So this conclude that the

400,000 element model was appropriate for this analysis.

And the mesh finite element model, that's why -- the mesh on the local areas within the sandbag region will be shown in the next few slides.

So next slide.

MEMBER ABDEL-KHALIK: This is sort of a quasi-transient model or is it sort of --

MR. KU: It's a quasi-static.

MEMBER ABDEL-KHALIK: Static.

MR. KU: Pure static loads.

MEMBER ABDEL-KHALIK: Pure static.

MR. KU: All right. Slide No. 48. Figure 4-18 shows the elevation view of the meshed 400,000 element model. As you probably see, there is a black band, black line or black stripe below the vent headers and that is actually the sandbed region. It looks black because of the very small mesh size used, you know, .75 inch square compared to a 35 feet radius vessel, so very small.

Okay. Let's move forward to 49. This slide contains two figures looking from the top and the bottom of the model. The figure to the left, I'm pointing to the screen to my right, Figure 4-19 is the top view of the finite element model looking down on the top head.

And Figure 4-20 is the bottom view of the model looking from -- looking at the underside of the model. Again, this black ring, you know, inside of the vent pipes are the sandbed region and the light shaded circle inside that ring is the embedded region, which are subject to two radial boundary conditions.

All right. Let me --

MEMBER ABDEL-KHALIK: So in this --

MR. KU: Yeah?

MEMBER ABDEL-KHALIK: -- transition it seems like a very sharp transition.

MR. KU: Right.

MEMBER ABDEL-KHALIK: From region at --

MR. KU: Right. We have some closer views of the mesh on those areas.

MEMBER ABDEL-KHALIK: And that doesn't cause you any troubles?

MR. KU: No, because of the boundary condition that is applied at the embedded regions. So if you fix the nodes over there, the mesh becomes -- the results become insensitive to the mesh, so you fix the nodes.

MEMBER ABDEL-KHALIK: You are in a region where the constituted equations are linear, right?

MR. KU: Um-hum.

MEMBER ABDEL-KHALIK: Okay. Otherwise this would be okay.

MR. GALLAGHER: Right.

MR. KU: All right. Let me quickly point to the areas that have local thinning. Bay 1 is horizontal to the left. And then you have Bay 11 -- I'm sorry, Bay 1, Bay 13, 15, 17 and Bay 19. So we have more detailed view of these five bays in the next five slides.

Let's move forward, Slide No. 50. This is the mesh details for Bay 1. It contains a 51 inch diameter locally thinned area. The mesh size within this area is the -- the nominal mesh size is .75 inch square. Again, the mesh size on the remaining sandbed region is 1.5 inches square. Let's put these figures in perspective.

The region to the right of the sandbed region is the vent pipe. The region to the left is the embedded region.

MEMBER ABDEL-KHALIK: This is just a hole, correct? This --

MR. KU: No, it's --

MR. GALLAGHER: Thin area.

MR. KU: -- thinned area, not hole.

MEMBER ABDEL-KHALIK: But there is free space on the other side?

MR. KU: No. We used the thickness that was --

MR. GALLAGHER: Free space. It's free space on the other side. This is the --

MR. O'ROURKE: It's like a depression.

MR. GALLAGHER: This is the shell.

MR. O'ROURKE: The shell.

MEMBER ABDEL-KHALIK: Yeah, so the depression is --

MR. GALLAGHER: So this is the thinned area that is in the shell.

MEMBER ABDEL-KHALIK: It's a --

MR. KU: It's a continuous areas.

MEMBER ABDEL-KHALIK: It's a 3-D element, isn't it?

MR. KU: Um-hum.

MEMBER ABDEL-KHALIK: Or is it just --

MR. GALLAGHER: Yeah. So each element has an area in thickness.

MEMBER BANERJEE: Okay. So there is no resolution in the thickness direction?

MR. KU: No. It's really thickness, yeah.

MEMBER BANERJEE: It's one --

MR. KU: It's one thick --

MEMBER BANERJEE: It's like shallow water areas. So it doesn't know if it's on the outside or the inside?

MR. KU: It doesn't matter.

MEMBER ABDEL-KHALIK: It assumes it is centered on the --

MR. WILKOWSKI: Yeah, mid-plane thickness, right.

MR. GALLAGHER: It ends.

MR. KU: Thank you, Gary. Okay. Now, let's move on to --

MEMBER ABDEL-KHALIK: For clarifying this to a novice in this business.

MR. WILKOWSKI: You're welcome.

MR. KU: Let's move on to Figure No. 51. This shows the mesh detail for Bay 13. It contains an 18 inch diameter locally corroded region in between the vent header -- the vent pipe, actually, I'm sorry. The vent pipe is to the left of the picture and then the embedded region. So it's kind of in the middle of the two regions. The mesh size for that area is the same, .75 inch square.

Okay. Now, 52, Slide 52. So this is the mesh detail for Bay 15, the local thinning area has the diameter of the same as Bay 13, 18 inch diameter. This figure might give you the illusion that the area is larger than the Bay 15, but I want to note that this figure was created at a closer zoom level to the model, so it looks bigger in the picture, but the size is also 18 inch in diameter.

Now, I'll move on to 53. 53 is the mesh pattern for Bay 17. It contains two locally thin areas. There is an 18 inch diameter, a thinner thickness circle of 18 inch diameter within the 51 inch diameter circle, but both -- since both circles, you know, use the same mesh size of .75 inch square.

And you might say that the 51 inch circle overlaps the vent pipe. But for the purpose of the analysis, we assumed there is no corrosion on the vent pipe reinforcing plate. So the corrosion stops at the interface of the vent pipe.

MEMBER BANERJEE: So when you refined it, did you refine it uniformly like you just cut down things or did you refine regions?

MR. KU: We, in essence, just tell ANSYS to use a smaller nominal mesh size and ANSYS decide what is the actual resulting size of the element here, if it thinks it is appropriate to create good mesh.

MEMBER BANERJEE: Good mesh is, again --

MR. KU: Acceptable.

MEMBER BANERJEE: I don't know what that means. There is, obviously, some sort of -- yeah, anomaly --

MR. KU: Right.

MEMBER BANERJEE: -- in certain spots.

MR. KU: Right.

MEMBER BANERJEE: So ANSYS is not perfect, I take it.

MR. KU: Right.

MEMBER BANERJEE: But when you start to say do it for the million mesh points, what does it look like, at this point? Does this region that you're showing get refined?

MR. KU: It will be all black, yeah.

MEMBER BANERJEE: Is it mainly concentrated in some regions?

MR. KU: No, we reduce the mesh size consistently on all the regions. If you go back to a Table 4-2 --

MEMBER BANERJEE: So let's say you double the number of mesh --

MR. KU: -- 5-46. Huh?

MEMBER BANERJEE: You double the number of mesh points.

MR. KU: Right.

MEMBER BANERJEE: So within this say Slide 53 --

MR. KU: Um-hum.

MEMBER BANERJEE: -- you get twice as many mesh points.

MR. KU: Elements, right.

MEMBER BANERJEE: Elements.

MR. KU: Right.

MEMBER BANERJEE: In this region.

MR. KU: Eventually.

MEMBER BANERJEE: Twice as many in every region?

MR. KU: Right. As it turns out, we get more --

MEMBER BANERJEE: But would the pattern also change somewhat?

MR. KU: Huh? What is it?

MEMBER BANERJEE: Does the pattern change or does it just --

MR. KU: It doesn't change.

MEMBER BANERJEE: -- because these are not quadrilateral elements, right?

MR. KU: Um-hum.

MEMBER BANERJEE: There's some triangular elements.

MR. KU: The majority is quadrilateral elements, as you can see from the figure.

MEMBER BANERJEE: Yeah.

MR. KU: So mostly they are four sided elements. And we have -- only a few locations you have those triangulares. So majority will be four sided, you know, mesh.

Okay. If there's not any more questions, I'll go to the last slide of my presentation.

MEMBER ARMIJO: I just want to ask a quick question --

MR. KU: Okay.

MEMBER ARMIJO: -- on the discontinuity between thicker areas and thinner areas. You know, you have this, let's say on 50, but it applies to all of them. Away from the -- on the other side of the vent pipe where the sandbed region -- below the sandbed region, you say it's thicker there? You have a thickness discontinuity? And how does -- how is that handled? Is that significant?

MR. KU: Well, as I mentioned earlier, the change in shell thickness is all step change. So we have a step change in thickness from thin to thick right at the interface. And the region you are pointing out is actually the embedded region.

MEMBER ARMIJO: Okay.

MR. KU: We apply radial boundary conditions to it, so the mesh will -- the mesh becomes -- due to the boundary conditions applied, the mesh density becomes insensitive.

MEMBER ARMIJO: Okay. So it's really clamped there?

MR. KU: Right, right.

MEMBER BANERJEE: So if I understand it, you really have, as you have integrated across the shell thickness in this, got a 2-D model, but with -- at the edges of this, of elements, you can have 3-D forces.

MR. KU: Yeah, we call it 2.5-D.

MEMBER BANERJEE: Yeah.

MR. KU: It's 2-D model in 3-D space.

MEMBER BANERJEE: Because it's integrated across the thickness.

MR. KU: Right.

MEMBER BANERJEE: So you've got only at the -- I don't know where the force is at, maybe at the nodes or wherever, but the fact that you have got a 3-D element coming off a 2-D is only reflected by the forces, right, or am I wrong?

MR. KU: Right. It's based on the mid-thickness of the element. So what we assume is the amount of rotation and displacement on the element -- what are you talking about the mid-plane or the out -- what we call the out-extreme fiber, the outside/inside surface of the shell is the same.

MEMBER BANERJEE: Yeah, so it is strictly 2-D.

MR. KU: Yeah.

MEMBER BANERJEE: Forces can be at angles, but --

MR. KU: Right.

MEMBER BANERJEE: -- that's it.

MR. KU: Right.

MEMBER BANERJEE: The force is where the nozzle is coming.

MR. KU: Right. So it's 2-D element in a 3-D space or you can have three dimensional loads.

MEMBER BANERJEE: So the fact that there is curvature in this --

MR. KU: Um-hum.

MEMBER BANERJEE: -- is reflected by the interaction between elements, the angle, the force acts between an element.

MR. KU: Right.

MEMBER BANERJEE: That's the only way. Because the element itself is a flat element.

MR. KU: Right. So if I say you have a pressure load, it would be normal to the element area.

MEMBER BANERJEE: Yeah.

MR. KU: The element is flat.

MEMBER BANERJEE: That's why when you said 3-D, I thought it was a resolution across the shell. Of course, that would be more expensive.

CHAIR SHACK: Interior, it's not actually symmetric in shell space, yeah.

MEMBER BANERJEE: Thick shell, yeah.

MR. KU: Let's finish up my session on Slide No. 54. 54 is the mesh pattern for Bay 19. It contains a 51 inch diameter circular area, also overlapping the vent pipe. Nominal mesh size is also .75 inch square in the locally thinned area. And the sandbed region, again, is 1.5 inches.

So the left of the figure is the embedded region. The right side is the vent pipe. Oh, this concludes my session for the finite element model. Is there any more questions?

MR. GALLAGHER: And I guess before we do get into this, just to step back and see where we are. So we went through, you know, some background. We went through description of the containment. We went through our thickness inputs and then how the model was built.

So going forward, and Stan Tang will be doing a lot of the presentation and Dr. Miller will talk about the codes, the loading -- the load combinations, the use of the modified reduction factor, our buckling results and we will begin like the stress evaluation that was done. And then we will wrap up with conclusions.

So that's basically where we are at in the presentation. So if -- are there any other questions or should we move on? Okay. So, Stan, if you can start on the codes and standards?

MR. TANG: Okay. Thank you, Mike. I'm Stan Tang from --

MR. GALLAGHER: Put your mike on.

MR. TANG: I'm Stan Tang from Structural Integrity. I'm going to discuss the codes and standards.

Next slide, please. The Oyster Creek Drywell vessel was designed, fabricated and constructed in accordance with 1962 Editions of ASME Code, Section VIII and Code Case 1270N-5, 1271N-5 and 1272N-5.

The Code Case 1270N-5 is to provide requirements for use in the reactor vessels. The Code Case 1271N is to provide additional requirements for safety in pressure vessel to be used as nuclear vessels. And Code case 1272N-5 is to provide additional requirement for stresses classification and stress allowables.

Original Code of Record and Code Case do not provide specific guidance in two areas, which is local membrane stress and post-accident conditions.

For the size of the region of increased membrane stress, guidance are sought from the 1989 Edition of ASME Code, including Winter 1991 Addenda, Section III, Subsection NE, Class MC components.

And for post-accident stress limits, Standard Review Plan Section 3.8.2 was used as a guidance.

MEMBER SIEBER: Those two references, neither one of which are part of your licensing basis, right? You use them strictly as guidance?

MR. GALLAGHER: No, these are our licensing basis.

MEMBER SIEBER: Oh, that is your licensing basis. Okay. Thank you.

MR. TANG: The next topic will be the

loading input. Next slide, please. This slide shows the individual locations that we consider, which including operating pressure and temperatures, dead weight loads, mechanical and live loads, which are the loads on the well pants beam supports and equipment hatch.

Penetration load including the dead weight and piping load. For penetration where the piping analysis were performed, end close from piping analysis were used and these piping load including pressure, dead weight, thermal and seismic.

For penetration with other piping analysis, piping dead weights from the portion of the pipe adjacent to the penetration bays on the maximum span between the pipe support was used. It also included the valve weight, assuming there is one in that piping maximum supported span.

The refueling load is the water load on top of the reactor vessels when -- during the refueling outage.

MEMBER SIEBER: Let me ask, in the penetration loads, did you consider dynamic loads due to flows through these penetrations?

MR. TANG: These loads are from the piping analysis, which is usually including the thermal pressure and seismic.

MEMBER SIEBER: But not flow?

MR. TANG: Pardon me?

MEMBER SIEBER: But not flow? No?

MR. TANG: I don't think so.

MEMBER SIEBER: Okay.

MR. TANG: They hydrostatic load is the water flow --

MEMBER BANERJEE: The live loads, they don't include any flow induced stresses?

MR. TANG: Pardon me?

MEMBER BANERJEE: The live loads don't include your flow induced loads?

MR. TANG: No, these are live loads. That is on the well pant and beam support.

MEMBER BANERJEE: Okay. So I still then-- Jack's question, I still want to understand what you do. Because due to flow, you're going to have certain loads, right, on the structures in the reactor? They will exert some loads on the drywell penetrations and things. So how is that taken into account then? That's what I'm not -- so you've got drywell penetrations, right?

MR. TANG: Right.

MEMBER BANERJEE: To which there is flow.

MR. TANG: Uh-huh.

MEMBER BANERJEE: Right. And then when you turn the flow on and turn it off, you're going to get different loads, right? So how are you going to take -- how is that accounted for? I'm sure you do, but I'm just asking.

MR. TANG: Those conditions are coming from the piping analysis.

MEMBER BANERJEE: Okay. So that's how it is fed back?

MR. TANG: Right, yeah.

MEMBER BANERJEE: Through the piping.

MR. TANG: Right, piping analysis. Usually they did the piping analysis and they have a anchor point at the penetrations. And the piping --

MEMBER ABDEL-KHALIK: You're blowing out his earphones.

MR. TANG: And the piping analysis for wide set of load is due to other operating conditions. So those piping analysis are anchor loads at the penetrations. So you -- essentially, we applied those set of piping loads onto the penetrations.

MEMBER BANERJEE: That came out of a separate analysis.

MR. TANG: Yeah.

MEMBER BANERJEE: Somebody did that.

MR. TANG: It all came from a separate analysis.

MEMBER BANERJEE: Yeah, okay.

MEMBER SIEBER: Okay. I think that's something that we need to have looked into a little bit further.

MEMBER BANERJEE: No, it's okay. Whatever.

MR. TANG: Okay. The hydrostatic loads is the water fronting loads during the post-accident condition in the drywell. And we also including the seismic loads which we analyzed using the updated response spectrum for the normal and for the conditions and also including the seismic anchor movement and also using the critical damping values of 2 percent for OBE and 4 percent for DBE.

Also, we looked into the accident load which is impingement loads in the drywell.

MEMBER BANERJEE: So where is -- is this also prescribed for you, what accident loads are?

MR. TANG: Actually, we look into the -- in impingement loads, but we did not analyze it. We essentially base on the past analysis and using those results and seeing that the certain impingement load is not one of the controlling load combinations.

MEMBER BANERJEE: Okay.

CHAIR SHACK: But I mean, these loads are basically the same as GE used in their design basis analysis. Has anything changed?

MR. GALLAGHER: Yeah, no. We used, you know, all the design drawings and the licensing basis inputs into this analysis. The only thing that we changed was the thickness inputs. And one clarification, I think, we will get into is the seismic loads, seismic spectra. There wasn't a specific one for the flooding, when the containment is filled with water up to elevation 74.6. So we had -- we ran a seismic spectra for that and included that. So that's what we ended up doing.

MEMBER BANERJEE: GE had done also the analysis after you removed the sandbed, correct?

MR. GALLAGHER: Yeah, that was the original licensing basis analysis we talked about that was done in 1992.

MR. TANG: These are a significant loads and also the load combinations. The -- we look into all individual loads, including the hydrodynamic loads, such as that, impingement load and the load combination based on the ASFAR and SRP and from the previous analysis and the reports.

And the first load combination is that design test, which is classified as Service Level A Conditions, which including the internal pressure, gravity, OBE and seismic anchor movements.

The next one is a normal operating condition, which is classified as a Service Level A, which including the external pressure, gravity, mechanical/live load, OBE, seismic anchor movement, external piping loads and thermal.

The third one is a refueling condition which is classified as A or B, which is the same as the normal operating condition with the addition of the dead weight of the water, reactor water at the top of the reactor vessels.

The last one is a post-accident condition which classified as Level C per Oyster Creek FSAR and that including the external pressure, gravity and mechanical live loads, SSE, seismic anchor movement due to SSE, external piping load due to SSE and flooding water level to elevation of 74 feet 6 inches.

And from -- among all these load combinations it is determined that the refueling and the post-accident fronting conditions are the most controlling load combinations.

Buckling evaluations. For buckling evaluations, we used the -- we followed the allowable stresses value per NE-3222 of the 1989 Edition, with Winter 1991 Addenda, of the ASME Code, Section III, Division 1, Subsection NE and Class MC components.

We use Eigenvalue buckling approach and we extract the first 200 buckling modes which is sufficient to evaluate all significant deformation mode in the drywell components.

MEMBER BANERJEE: So just educate me a little bit. You have now got a displacement field out of your calculations? From that you are extracting the Eigenvalues?

MR. TANG: Right.

MEMBER BANERJEE: And you are sort of fitting a global spectral analysis to the displacement field to extract that?

MR. TANG: No. Actually, I want to take this opportunity to address the same questions.

MEMBER BANERJEE: Yeah.

MR. TANG: To extract the -- Mr. Abdel-Khalik asked a little bit earlier. To extract a buckling mode, you need to apply the loading conditions. So all our loading conditions are in the drywells and we did not apply any loading on the vent headers and downcomers.

Okay. So that's why some of those buckling mode that thought was mentioned in the downcomer, essentially, is not relevant to our analysis.

MEMBER BANERJEE: Right. Okay. That's clear.

MR. TANG: So I just thought of that aside.

MEMBER BANERJEE: But you are looking at--

MR. TANG: I found the question a little bit --

MEMBER BANERJEE: You are looking at --

CHAIR SHACK: Let me see if I can answer my own question. I think Dr. Miller can probably help me out. The theoretical buckling load is lower for the vent header, but I haven't applied by capacity reduction factor yet. And so when I apply my capacity reduction factor, the shell is going to be controlling, because the capacity reduction factor for the vent header is a whole lot bigger than it is for the shell.

MR. MILLER: And that's basically why the shell controls the buckling.

MEMBER ABDEL-KHALIK: We don't know that

for sure, do we?

MR. MILLER: Pardon?

MEMBER ABDEL-KHALIK: We don't know that for sure, do we?

CHAIR SHACK: He does.

MR. MILLER: I would say that was a definite yes.

MEMBER ABDEL-KHALIK: So the analysis has been carried through all the way?

MR. MILLER: Buckling value.

MEMBER ABDEL-KHALIK: That would show you that this is indeed the case?

MR. MILLER: I don't have a knock-down factor of 1.0 versus maybe --

COURT REPORTER: Dr. Miller, can you get on the mike?

MR. MILLER: Okay. Clarence Miller, independent consultant. I was saying that I -- the drywell shell will be the critical area for buckling, because the piping, basically, won't be subject to buckling because of the R/t ratios. So it's a relatively rigid shell versus the drywell. The drywell is quite flexible since it has a large radius to thickness ratio.

MEMBER ABDEL-KHALIK: Let me try to ask my question a little more directly.

MR. MILLER: Okay.

MEMBER ABDEL-KHALIK: Is there any scenario in which the vent pipes can actually fail without the drywell spherical region failing or not meeting the code requirement?

MR. MILLER: I would say I can't think of any. I mean, we would have to have some load condition that is not considered in the design, some external loading would have to be applied other than the ones that we have talked about, the seismic loads or the accident loads and so forth.

MEMBER ABDEL-KHALIK: Now, the statement was made that those loading conditions were not applied to the vent pipes. They were just applied --

MR. TANG: Exactly.

MEMBER ABDEL-KHALIK: Okay. Now, had those loading conditions been applied to the vent pipes, do we know what the safety factor for the vent pipes would be?

MR. TANG: As Dr. Miller mentioned, those components really highly resistant bucklings. So if there is any safety factors, it would be very, very high.

MEMBER ABDEL-KHALIK: But that's

intuition.

MR. TANG: Yes.

MR. GALLAGHER: Yeah, but we didn't study this, Dr. Khalik, so, you know, we can't give you a number or anything like that. I guess what, you know, Dr. Miller is saying, based on his experience, is that the shell would be the -- the drywell shell would be the area of interest based on the loads that are applied and that would be the area that would buckle before anything else.

MEMBER ABDEL-KHALIK: Okay.

MR. GALLAGHER: And so that's why it was studied that way.

MEMBER ABDEL-KHALIK: Would -- I have to use my words carefully. Would failure of the vent pipe constitute failure of the system?

MR. GALLAGHER: Um, well we could consider that and, you know, so the vent pipes have been designed to the, you know, correct codes and standards, so, you know, the loading that is applied has to go through the shell.

MEMBER ABDEL-KHALIK: So you are relying on your statement on the original design basis of the vent pipes?

MR. GALLAGHER: That they meet the

original design?

MEMBER ABDEL-KHALIK: That they meet the original.

CHAIR SHACK: Yeah, but I think both Dr. Miller and I are saying that the buckling load of the vent header really is much higher. It's --

MR. TANG: Uh-huh.

CHAIR SHACK: -- lower as a theoretical answer, but that's because we haven't applied the correction factor yet to it and we sort of both agree that with those R/ts, this is a thick wall thingy. It is 1 versus .2 to .4.

MR. MILLER: Yes.

CHAIR SHACK: That is going to make a big difference.

MEMBER BANERJEE: In any case, if I understand it, the phenomenon you are trying to study is thinning of the shell in certain regions.

MR. GALLAGHER: Um-hum, correct.

MEMBER BANERJEE: Everything else is unaffected from the original design basis.

MR. GALLAGHER: That's correct.

MEMBER BANERJEE: So in some sense, that's a way for the effect, if any, to occur.

MEMBER ABDEL-KHALIK: I fully understand

that. But if, as a part of the analysis, we discover that there is a component that is -- had been inadequately designed, it's incumbent to identify that.

MR. GALLAGHER: Right. And actually--

MEMBER ABDEL-KHALIK: It's upon us to identify it.

MR. GALLAGHER: Yeah. And actually we did study that in detail. Because if you look at, just for instance, and we're going to talk about this slide for a different purpose, but Slide 77, if we can go there for a minute, if you look at the cylinder, if you look at the table at the left, we did look at every area in the drywell and just as Francis said, the modeling was detailed.

The cylinder is actually the controlling location and there is, you know, virtually no degradation up in the cylinder. So that is what it is, basically. You know, that's if we had the original calculation, it should be, you know, similar to that. And basically, what we have done is evaluate the effect in the sandbed.

So we did -- you know, we just did not just look at the sandbed, we looked at the entire structure. And had we found a problem elsewhere in the structure, we would be talking to you about that, but we did not.

MEMBER BANERJEE: But that's in the refueling case, right? In the flooding cases --

MR. GALLAGHER: That particular one. In the flooding case, the limiting area is the sandbed, right.

MR. WILKOWSKI: So what might have been helpful to me in reading your report of January is where you have these 200 different modes listed is even if you had some comment as to where those modes occurred, and maybe -- obviously, I don't want to look at 200 mode shape drawings, but, you know, maybe some of the pertinent ones as to what the mode change looked like in the sandbed region, that would be helpful.

MR. TANG: Actually, the -- we do have the figures on the buckling deformation mode in the report for the significant ones. Okay.

MEMBER BANERJEE: Which was the most controlling one?

MR. GALLAGHER: Yeah, if you look at the report, maybe we can show that, because there were some. You can see the mode shapes.

MEMBER BANERJEE: Do you have it on a

slide?

MR. GALLAGHER: No, I don't think they are in here, Stan. I think they are in the detailed backup analysis.

MR. TANG: Yeah, okay.

MR. GALLAGHER: So we do have some, we have some of that here we can show.

MEMBER BANERJEE: Well, that's okay.

MR. GALLAGHER: The other report.

MEMBER BANERJEE: If it's in the report, we can see it.

MR. GALLAGHER: Well, it's in a calculation we have.

MEMBER BANERJEE: Yeah.

MR. GALLAGHER: So let's pull that up and we can show it to you, even at a break or whatever, but it has, basically, these mesh models and you can see the mode shapes. And as Stan said, it has some of the significant modes and you can see where, you know, it is exaggerated, obviously, on the -- in the figure. But you can see where those mode shapes occur.

MEMBER BANERJEE: Okay.

MR. GALLAGHER: So we can show you that.

MEMBER BANERJEE: These Eigenvalues are for this here?

MR. TANG: For the whole component, for the whole drywell.

MEMBER BANERJEE: For the whole thing?

MR. TANG: Yeah, whole drywell thing.

MEMBER BANERJEE: Including this?

MR. TANG: Yeah, each mode that buffers the point load in the report, essentially, is corresponding to the different mode shape in the different locations.

MR. WILKOWSKI: So Bill Shack and I had -- and my colleagues speculated that the first 10 all zero modes that you had might have been some place other than the main shell.

MR. TANG: Exactly.

MR. WILKOWSKI: It could have been in a star-truss --

MR. TANG: Yes, those are the --

MR. WILKOWSKI: -- or downcomer or some place. And if you had just indicated in a comic column where those mode shapes occur, that would have been --

MR. TANG: Okay.

MR. WILKOWSKI: -- obvious.

MR. TANG: Yeah, yeah. Because the -- those mode shapes, if I remember correctly, is in the vent header. And remember, in order to obtain a mode -- a buckling deformation mode shape, you have to apply the loads. If you don't apply the load, you don't know how the structure buckles.

Since we are non-concentrating or not analyze at buckling of the vent pipe and downcomer, so we did not apply the load in those locations. Those components -- because those components are used only for the -- in the phase in stiffnesses. So we -- that's why, you know, some of those mode shape results are evaluations.

MEMBER BANERJEE: So they are without load, but you have it coarsely nodalized, so that at least vessels are transmitted through them, right?

MR. TANG: Yes, but --

MEMBER BANERJEE: I'm trying to understand your model. So you have no loads on them.

MR. TANG: Right.

MEMBER BANERJEE: But they are transmitting the boundary condition to the shell, to the point where they are joined to the shell. Is that right?

MR. TANG: Um --

MEMBER BANERJEE: They are still elastic components, aren't they?

MR. TANG: It's still elastic, but you don't have an actual loading apply onto the vent header and downcomer. So it's very difficult to determine the mode shapes. Yes?

MR. GALLAGHER: So we have a report. The report here shows various mode shapes and you can -- if you like --

MR. WILKOWSKI: Well, I think we just had too much information there that could have been filtered.

MR. GALLAGHER: There is a lot of --

MR. O'ROURKE: As an example, this is the buckling mode shapes for the refueling case, all 200 of them.

MR. WILKOWSKI: Ah, geez.

MEMBER BANERJEE: But you can look at the most --

MR. O'ROURKE: With numbers and figures.

MR. WILKOWSKI: Ah, okay.

MEMBER BANERJEE: Which is the worst -- I guess that's the question. Which is the worse case and what does it look like?

MR. GALLAGHER: You need to see this, Stan?

MR. TANG: Yeah.

MEMBER BANERJEE: Just give the figure number.

MR. GALLAGHER: The cylinder.

MR. TANG: The cylinder.

MEMBER BANERJEE: The separate one?

MR. GALLAGHER: The cylinder is, you know, the area where a lot of the mode shapes are.

MEMBER BANERJEE: Well, that's for the refueling case, right?

MR. TANG: Yeah, right, yeah. You test -- so an example --

MR. GALLAGHER: This particular is refueling. There is flooding.

MEMBER BANERJEE: The flooding case is--

MR. GALLAGHER: Okay. Where are the mode shapes in the flooding?

MR. TANG: So this is the buckling boundary in the cylinder portion.

MEMBER BANERJEE: Oh, okay. And what about the flooding case?

MR. TANG: Pardon me?

MEMBER BANERJEE: The flooding case? Maybe you can just pass it around.

MR. TANG: Okay.

MR. GALLAGHER: Do we need to go into this some more or --

MEMBER BANERJEE: This is the --

MR. WILKOWSKI: I do want to see the flooding sandbed modal shape. And we could do that off-line. I don't know if we need to do that right here.

MR. GALLAGHER: Should we do that? Dr. Shack, should we continue this off-line or --

CHAIR SHACK: Yeah, I think we can do this off-line.

MR. GALLAGHER: All right. Stan?

MR. TANG: This is the typical buckling motion.

MEMBER ABDEL-KHALIK: Could you, please, explain to me how do you run this analysis without applying any load on the vent lines? How is that -- what does that mean?

MR. TANG: What it means is that you need to do a -- in order to determine the buckling mode, okay, you need to -- loaded the components, okay. So since we are concentrating on the buckling of the drywells, so he says --

MR. GALLAGHER: I think what he was trying to say, Dr. Khalik, is we simply just modeled this as a matter condition, so the loads are transmitted from the shell to the support through the vent headers, okay, onto the support. But if you wanted to do a buckling evaluation of the pipe, then you have to apply the loads, like at the pressure vessel, on the pipe itself, to then calculate load factors to then calculate your buckling factors.

So that wasn't done, because we didn't study the vent headers. Okay. So that -- I think that's what you're saying, right?

MR. TANG: That is exactly why.

MR. GALLAGHER: So you know, we used this -- so we could have, like I said earlier, just cut off the vent headers and applied an artificial support to show, you know, that the load is supported. It would be transmitted through the support which is supported for us which goes to the basement. But what we did is we tried to mimic the way it would be distributed and all the individual supports.

But the loads, the load does go through the vent headers and goes to the support. You know, that's the way it's constructed. But to calculate the buckling of the physical structure of the pipe, you would have to, you know, have all the load and load combinations on that pressure vessel, calculate load factor and then calculate the buckling factor.

MEMBER ABDEL-KHALIK: So what does it mean when you tell me that the first 10 modes happen in that park?

MR. TANG: Because the vent header and the downcomer are including in the model, so when you ask the software to try to extract the buckling mode, it would also try to determine whether there is any buckling in the vent pipe. But since we did not apply any load, so, essentially, what it is is that the software doesn't know what to do.

MEMBER BANERJEE: Because you applied no load, there was no displacement.

MR. TANG: Exactly, yeah.

MR. WILKOWSKI: It probably shouldn't have been included in the table.

MEMBER BANERJEE: But maybe, for the record, you could just give us the slide -- I mean, the figure numbers we are passing around, so that at least we know we have the figures.

MR. GALLAGHER: Okay. When they come here, we'll announce what the figure numbers are. Okay. So any other questions on that point then? Okay. So, Stan, I think we're still --

MR. TANG: Let me continue, I think. We use Code Case N-284-1 for the capacity reduction factors including the effect of tensile hoop stress. The load factors obtained from the buckling modes are based on the buckling mode shape deformations.

And analysis is for the refueling case for the normal operating conditions and also done for the post-accident flooding case.

MEMBER BANERJEE: To just go back to Said's question, which I guess you could have just applied the boundary condition really at -- where the pipes join the system for all intents and purposes, right?

MR. TANG: Yeah, yeah. We could have cut it off at the bellow conditions.

MEMBER BANERJEE: Yeah.

MR. TANG: Okay. And then say, you know, apply some kind of boundary condition depending on that.

MEMBER BANERJEE: Because the other part really is not participating.

MR. TANG: Yes, the reason that we did that is we thought that it would provide a better representation of the stiffnesses in the phase between the vent pipe and the vent header from the, you know, stress analysis point of view.

CHAIR SHACK: Okay.

MR. TANG: Okay. Next slide, please, 62. The buckling evaluations performed per ASME, NE-3222 and Code Case N-284-1, which specified that the allowable factors of safety for Level A/B is 2, for Level C is 1.67, for Level D is 1.37 -- 1.34, which we did not use. It just included for reference purposes.

MEMBER BANERJEE: What do you really mean by factor of safety here?

MR. TANG: What I mean is that your buckling stresses has to be, for instance, in the Level A or B condition has to be 2 times less than the theoretical buckling.

MR. GALLAGHER: Yeah, it has to be half.

MR. TANG: Yeah.

MR. GALLAGHER: Yeah, for the theoretical stress.

MEMBER BANERJEE: The theoretical stress for what?

MR. GALLAGHER: For buckling.

MEMBER BANERJEE: For buckling with imperfections or without imperfections?

MR. MILLER: Well, wait, let me answer that. The safety factor is a ratio of the calculated stresses from the applied loads divided by the predicted or calculated failure stress of a shell with imperfections. So it includes the --

MEMBER BANERJEE: With imperfections?

MR. MILLER: Yes.

MEMBER BANERJEE: And based on that analysis of Koiter that was referred to in Hutchinson's letter or is it something different?

MR. MILLER: No, let me -- when I get into my part of it, I will --

MEMBER BANERJEE: Clarify this?

MR. MILLER: -- give you an explanation of how the capacity reduction factors are obtained.

MR. GALLAGHER: And I think we're actually here at this point.

MR. MILLER: Oh, okay.

MR. GALLAGHER: So if we could go to Slide 63, this is where Dr. Miller would tell us about the modified capacity reduction factors.

MEMBER BANERJEE: Oh, okay.

MR. MILLER: I'm just going to read what is on 63 and then I will explain things. The ASME Code Case N-284-1 allows modifying the capacity reduction factor to account for the effect of orthogonal tensile stress on buckling strength.

The effect of orthogonal tensile stress due to internal pressure is well-documented for cylinders.

The N-284-1 capacity reduction factor is modified using formulas, which I have developed, from many tests. The formulas are based on tests initially conducted on cylinders.

Tests conducted on spheres, without internal pressure, show that the coexistence of orthogonal tensile stress reduces the effect of imperfections on the buckling strength of the spheres. Orthogonal tensile stresses can result from in-plane tension or compression loads. They don't need to be resulting from internal pressure.

The modified capacity reduction factors which are used in the analysis, that you were talking about today, are given in ASME Code Case 2286-1 for spheres. The next slide will attempt to explain what the capacity reduction factor is.

What we have talked about so far with the finite element analysis is determining the buckling load for a shell that has a perfect radius in all areas. When a sphere is fabricated in the shop, it is with a press, you are forming it into the spherical shape and these pieces are brought out to the field and welded together. And the final sphere has some deviations from this theoretical shape.

The code has a limitation on the deviation from theoretical shape. Based on several thousand tests, I developed the relationship between the buckling of the perfect shell versus the fabricated shell as a function of these deviations from theoretical shape. And the formulas that are put into the code are based on the maximum permitted deviation from theoretical shape.

In the case of spheres, that deviation is one shell thickness. But the deviation is measured over a 1/2 wavelength of a buckle. And so for this deviation, the 1/2 wavelength is, approximately, 3.5 x the square root of R/t where R is the radius and t is the thickness or the perfect shell like you would get from the computer analysis that buckle length is much shorter. It's like .242.

And what we find out is there is two factors that are happening. If you have a complete sphere or a large sphere, you will have a very low buckling value. In fact, it -- for the code, if you have uniform external pressure, this coefficient is all the way down to .075 ET/r.

By adding some kind of restraint in the case of our sphere here, we have the knuckle at the top region and then we have a ring stiffener at an intermediate level and below that we have some radial beams which are attached to, it's termed, beam seats, and then below that is a lower beam seat.

So these -- because of the radial restraint provided by the radial beams, that prevents the -- well, I should say it limits the size of the buckle area. The length that we consider, we look at -- and my figure here where I have L1, L2, L3, if you envision between any one of these, you will have a buckle like a dimple. It will be like Dr. Shack mentioned in -- for axial compression, it will probably be oval in shape. It will be longer than it is wide.

But as we make those supports closer together, we can actually go all the way from where I commented about the reduction factor being 0.75. It might be as high as .5 just by adding the ring stiffeners or other means of providing this line of support.

The capacity reduction factor we talked about has two components. The first is one I have talked about so far where it's based on geometry. The second one is if the orthogonal stress intention, you will actually have an increase in the capacity reduction factor. And what is interesting is, based on a lot of tests, we found that even though the, what I term here as, alpha1L can vary anywhere from the .075 to .05.

The pressure component is not -- is independent of what that initial alpha1L value is. I'll show -- talk about that on a later figure.

On this slide, what I'm showing is the alpha1L is given by this relationship of 1.377 divided by M0.6 power. And M is a function of the wavelength. Of course, the smaller that value is, the higher this alpha is I'm showing you for -- if the sphere was under uniaxial compression only, you could go from .207 up as high as .67.

Now, I'll give you a relationship then for the alphap, which is the increase in capacity factor due to the tensile stress. And that relationship I'm showing you there is 1.752 divided by the quantity 3.24 plus 1/rho. And rho is the hoop stress times the radius divided by the modulus of elasticity and the thickness.

Let's go to the next slide then, Slide 65. I want to show you the vertical ordinate is this alpha value, which is a combination of the alpha1L or alpha0,

I call it here, plus alphap. And I'm saying that that is the buckling stress of a fabricated shell divided by the buckling stress of a perfect shell, one without imperfections. The sigma is the one that is determined from the finite element analysis.

I'm showing you the curve for alphap. This curve was based on 57 cylinders that were tested under combinations of axial compression and hoop stress. This is the 57 tests. There are probably over 1,000 independent test points. From those tests, I derived a lower bound value, which takes into account the permissible deviation that I talked about before for fabrication.

The tests by Yao I knew about those quite some time ago, but the more recent tests were performed by Odland on spheres. Both sets of tests were -- loads were applied where the hoop stress resulted from the applied axial loads as opposed to internal pressure.

You look up here from the sphere tests, I picked this curve, but actually, this curve is actually based on an imperfection of E/t of 1.8, so this is kind of showing you how conservative we are in using the alphap value for cylinders. And I'm still recommending that to the code committees until there is a lot more tests on spheres.

Another thing, there was some comment made by some reviewers about the fact that when you do the -- an analysis with a finite element analysis, why you have already got those hoop stresses in there. Aren't you accounting for those twice?

Well, when you do the finite element analysis of a spherical shell, you apply your maximum compressive load, no matter what the orthogonal load or stress is, the buckling value will be the same as that associated with this maximum compressive load.

So if you look at the curve we are talking about, it will just be from the finite element analysis, it will just be 1.0 all the way from uniform external pressure all the way to where you have an internal hoop stress equal to 3 times the failure stress. So that's one thing I was saying, I don't think we are accounting for the internal pressure with the analysis, because it doesn't reflect that.

Another thing, we have had a lot of discussion about penetrations. And you might ask what about those? Well, I have done a lot of tests that demonstrate that this is two independent effects. Penetration -- the effect of penetration versus the effect of imperfections.

I did a series of tests, as well as other researchers, where I loaded a shell with axial compression only and found a buckling value. These are elastic shells, so I was able to take the same shell and cut a hole in it and reload it and -- until I kept increasing the size of the hole until I finally got the buckling value to be less than it was without any hole.

And so relationships have been developed for what is the effect of having an unreinforced hole in a shell. Well, then by a series of tests, we determined, okay, well, if you do have an in-penetration, why what reinforcement do you need? And so the ASME Code gives you the requirements for the reinforcement so that this will eliminate the possibility of buckling being due to the hole as opposed to imperfections.

So that's why the code says if the size of the hole is below, I think it is something below, 3 inches, well, you don't even need to consider it. Actually, based on tests, why it could definitely be probably 6 inches and still not affect the buckling value.

MEMBER BANERJEE: So if you have a thinning region which is circular, it will be a bit like a hole, right?

MR. MILLER: Pardon?

MEMBER BANERJEE: It's a bit like a hole, isn't it, the thinning region?

MR. MILLER: We talk about, you know, being concerned about these very localized areas. Well, what I'm telling you is you could actually cut a hole --

MEMBER BANERJEE: Yeah.

MR. MILLER: -- at that location and it still would not buckle if it was a small enough area. So like the area talked about where it's a size of a dime, that would not, other than you might leak it, buckle.

MEMBER BANERJEE: Right. It has to get to a certain size --

MR. MILLER: Yes.

MEMBER BANERJEE: -- before it has an effect. What is that size?

MR. MILLER: Well, I would say that it's-- I actually have developed a relationship, but I would just right off, I would say if it's less than .5 square of R/t, why I don't think it would affect the buckling capacity.

MEMBER BANERJEE: .5 square root of R/t?

MR. MILLER: Yeah, which is certainly a

good size on this sphere.

MEMBER BANERJEE: So in this case, it would be how much?

MR. MILLER: Is it --

MR. GALLAGHER: Well, the R is the radius of the sphere.

MEMBER BANERJEE: Yeah.

MR. GALLAGHER: So that's like 35 feet, a nominal 1 inch thickness and square root, so what's that?

MEMBER BANERJEE: 35, right?

MR. GALLAGHER: 35 times 12 divided by 10 foot. 35 times 12.

MR. MILLER: 5 times 12 times the thickness.

MEMBER BANERJEE: Well --

MR. GALLAGHER: Square root of that.

MEMBER BANERJEE: -- you can keep it in feet.

MR. GALLAGHER: Yes.

MR. MILLER: Well, inches.

MEMBER BANERJEE: Divide by 12 so --

MR. GALLAGHER: Okay. So 35 divided by 12 is about 3, so squared 3 is what 1.7?

MEMBER BANERJEE: 1.5 feet.

MR. GALLAGHER: 1.7 feet, right?

MEMBER BANERJEE: Yeah.

MR. GALLAGHER: Feet.

MEMBER BANERJEE: Divided by 2.

MR. GALLAGHER: That was divided by 2?

MEMBER BANERJEE: By 5, yeah.

MR. GALLAGHER: Okay.

MEMBER BANERJEE: Yeah.

MR. GALLAGHER: So .8 feet. So three-quarters of a foot.

MEMBER BANERJEE: What's your largest region?

MR. GALLAGHER: 18 inches.

MR. MILLER: Just over 4 feet.

MR. GALLAGHER: 51 inches.

MEMBER BANERJEE: There is an issue.

MR. MILLER: What I'm saying also is that buckling is associated with the maximum stressed area and the conditions at that location. And the size of the area is related to this wavelength, where I said it was -- would be close to -- we're taking a measurement of over 3.5 square of R/t. So you probably could use the average values over that 3.5 square of R/t as a reasonable thickness to put into your finite element analysis.

MEMBER BANERJEE: So the more that they showed us, the picture that you handed around, had a wavelength of about the spacing between the vent pipes that come off?

MR. MILLER: Roughly, the vertical length, yeah.

MEMBER BANERJEE: Oh, okay.

MR. MILLER: Not the circumferential length.

MEMBER BANERJEE: Okay.

CHAIR SHACK: But I think for the regions we're interested in, we're basically at the .207 limit for alpha.

MR. MILLER: Yes, right.

CHAIR SHACK: So the only thing that we are really worried about is how much we add for the pressure correction.

MEMBER ABDEL-KHALIK: Now, you indicated that the capacity reduction factors correspond to the maximum allowable deviation from the ideal geometry, as specified in the code.

MR. MILLER: Yes.

MEMBER ABDEL-KHALIK: What is that maximum allowable deviation for this particular size spherical shell?

MR. MILLER: Regardless of the size of the sphere, it's -- deviation, maximum deviation is in terms of E/t where E is the deviation from theoretical radius and E is 1. Okay. So where the shell is 1 inch thick, we can have a deviation of 1 inch and a distance of 3.5 square of R/t.

Now, when the -- after the sphere was fabricated, then the fabricator had to come in with a sweep and actually take the measurement. So it's obvious in looking at the shell where there are deviations. So very detailed measurements are made of that sphere at the time of fabrication.

You only need to concern yourself with the inward deviations, because anything outward is going to actually increase the buckling value.

MEMBER ABDEL-KHALIK: And this verification has to be done only once prior to installation of this?

MR. MILLER: Yes. And it -- unless there was some accident or something that caused denser things, there would be no need to do it again. The other thing is you can always increase the buckling strength of shells by adding some stiffness, very significant increases.

Just in conclusion, I'm saying that, in my opinion, the capacity reduction factors that are used in the analysis are appropriate to the Oyster Creek shell.

MEMBER BANERJEE: But to some extent, the accuracy may not matter all that much in how well you estimate this, because you have very large safety factors, right? I mean, it looks like you still have very large safety factors.

MR. MILLER: Yeah, there is several, you know, conservative things that were still built in. The capacity reduction factor for each of these zones was based on the largest circle or dimple it could form. And the areas of the highest stress are -- typically are down near these vent pipes, which so those do restrict the buckling. And so even a lower or a smaller buckle would result. And so you could -- actually, if you went to every individual spot, you could calculate a different capacity reduction factor in which would be something you could actually deal with there.

MEMBER BANERJEE: I guess going back to Said's point though, I know it would have meant another calculation, but if you hadn't thinned it and done a calculation and thinned it and done a calculation, we would have known precisely what the effect was.

At the moment, we know we are far away from it. And I'll accept that argument, you know, but we don't know what it was like before it was thinned.

MR. GALLAGHER: Yes, and other than what was in the Sandia, but you know, again, we thought what our charge and commitment was --

MEMBER BANERJEE: Right, right.

MR. GALLAGHER: -- was to quantify the margin we have now. And that's what we did.

MEMBER BANERJEE: Right.

MR. GALLAGHER: So any other questions for Dr. Miller?

MR. WILKOWSKI: Yeah, I just want to follow-up on one more thing. When the shell analysis was done and we reduced the wall thickness there, the thickness is reduced equally from both sides, so that what we really get is we get about the stresses right. We get the R/t ratio pretty close. But we're -- often the eccentricity that occurs there somewhat. Do you feel that the capacity reduction factors that are here account for that appropriately?

MR. MILLER: Actually, in the rules you will see that there is a maximum deviation allowable at the welded joints. And so the thing you are concerned about we could look at that, but it's -- this is something measured over a distance of 12T and so the kind of deviation that you are concerned with does not exceed that allowable either.

I have been involved in a lot of finite element analysis where we actually are modeling, you know, the change in plate thickness. And the discontinuity stresses do not particularly affect the buckling, because buckling is a function of the membrane stresses and not bending stresses. That's one thing I found out in analyzing all these shell tests.

MEMBER BANERJEE: And did you have access to the report by Hutchinson?

MR. MILLER: Well, I don't know. I mean, I'm familiar with Professor Hutchinson, but I --

MEMBER BANERJEE: Does --

MR. MILLER: -- never had access.

MEMBER BANERJEE: The report that he wrote on the work, did you have a look at that?

MR. GALLAGHER: The report for you all? No, we haven't seen that.

MR. MILLER: No, I haven't seen that.

MEMBER BANERJEE: Okay. Because there was some concerns with regard to the code case itself. I don't know whether this is worth discussing or not.

CHAIR SHACK: Well, he had some concerns, basically, with the way the transfer stresses were handled within there in the case where you had sort of a proportional loading or a fixed uniaxial loading. But the crucial part of his comments for this particular case --

MEMBER BANERJEE: No.

CHAIR SHACK: -- is that for the application we have here, he felt the results -- he did what he thought was a conservative bounding analysis based on an axisymmetric imperfection in a spherical shell and the results that by and large we got here were somewhat more conservative than the results he got. So he, you know, had no problems with the values that they were using in the analysis, which again, you know, we may have some further discussion with the code committees.

But for the purposes of this discussion it, essentially, confirmed that the use of the capacity factors that had been selected.

MEMBER BANERJEE: Okay. That's a separate discussion, so I didn't want to bring it up. But if-- we asked you for your comments on --

MR. MILLER: On my comments. I might just comment. Over the years, I have been involved in a lot of studies where we tried to use the finite element programs where we included the actual measured imperfections. But in all of the studies made, we found out that the empirical equations, which I developed, are far more accurate than any of the finite element results.

The finite element, what I found was that if you had three different people do the analysis, whether including imperfections, you will get three different answers and they might be significantly different, because it is very difficult. I mean, I think Dr. Hutchinson probably inputted sinusoidal or that type of imperfections as opposed to the random type that you would --

CHAIR SHACK: But that is why he is arguing his is a bounding thing.

MR. MILLER: Okay.

CHAIR SHACK: In fact, if you make the whole axisymmetric imperfection, which is an unrealistic case, but the code in its usual way has included enough conservatism that is still conservatism over what he thinks is a bounding analysis. And again --

MEMBER BANERJEE: So if somebody else did this calculation, we would get a different answer?

MR. MILLER: Pardon?

MEMBER BANERJEE: If somebody else did the finite element calculation, we would get a different answer, you're saying?

MR. MILLER: Yeah.

CHAIR SHACK: No, no, he -- this is a linear elastic process.

MEMBER BANERJEE: No, no, I'm --

CHAIR SHACK: He is talking about --

MEMBER BANERJEE: He made the comment that it is more -- Dr. Miller made the comment that it is more accurate to use the empirical than the finite element, because if you have three different people doing the finite element analysis, you will get three different answers. I think that's what he is saying.

MR. MILLER: I'm saying if you try to include imperfections --

CHAIR SHACK: Yeah.

MR. MILLER: -- if you analyze the spherical shell with the assumed theoretical radius, I'm assuming whether you use ABAQUS or ANSYS, if you are one skilled in the art, you are going to get the same answers. Try to include imperfections.

MR. WILKOWSKI: It's probably the

difficulty in making the meshes consistently between one research group and another research group.

CHAIR SHACK: Well, even more --

MEMBER BANERJEE: Well, you are making me even more frightened now.

CHAIR SHACK: -- you're going to include the imperfection.

MR. WILKOWSKI: We've got to define imperfection.

MEMBER ABDEL-KHALIK: Well, I think they are doing a good job.

CHAIR SHACK: Well, if you are doing the imperfection analysis, you should -- you need a non-linear shell theory. Now, you can argue over which non-linear shell theory you can be using. You can argue over how you implemented that non-linear shell theory in a finite element analysis. I can see all those leading, but don't confuse what they did here with the linear elastic Eigenvalue analysis and non-linear shell theory analysis to try to account for imperfections.

MR. MILLER: Um-hum, um-hum.

CHAIR SHACK: So those are two different beasts.

MEMBER BANERJEE: So you are far from the limits?

CHAIR SHACK: Well, I think -- you know, no, you're not far from the limits. You are looking at different problems. There is a certain consistency here. The analyses have gone in the order that we expect from the GE axisymmetric finite element analysis to the Sandia finite element analysis to this finite element analysis in a consistent way.

You know, there is no, I think, real discrepancies between the two. But again, if we were off dealing with a non-linear shell problem trying to analyze the problem completely from a finite element analysis, including imperfections, yes, you might get a very different set of answers.

MEMBER BANERJEE: Well, what do you mean by non-linear here?

MR. MILLER: Essentially, to --

MEMBER BANERJEE: Non-linearity in the conservative equation or in the displacement?

CHAIR SHACK: Basically, in the displacement. It, you know, still may be elastic, but you no longer have small displacements.

MR. MILLER: You have to continually apply the load and steps. Because instead of just --

MEMBER BANERJEE: I'm a hydrodynamicist,

so I --

MR. MILLER: -- you have to look at things as always being non-linear.

MR. GALLAGHER: Okay. Dr. Shack, that concludes our buckling evaluation part of the presentation. I just want to do a little check with you. Where we are going further in the presentation is the stress evaluation and then the summary, the sensitivity.

CHAIR SHACK: Sensitivity.

MR. GALLAGHER: So we could go through the stress evaluation, if you want, but we oriented the presentation to do the buckling first, because we thought that was the more area of interest. The rest, the stress evaluation part, basically, just goes through and says we did the stress evaluation and we met all code allowables.

If you would like us, we could go through it in detail or we could go to the next section, if you want to, this is a time check.

CHAIR SHACK: I think we have enough time. So why don't you just --

MR. GALLAGHER: Okay.

CHAIR SHACK: -- go through it.

MR. GALLAGHER: Okay.

CHAIR SHACK: I don't think we have to spend a lot of time on it. Obviously, the thing that is of greatest interest to us is the sensitivity analysis.

MR. GALLAGHER: Right, right.

CHAIR SHACK: But --

MR. GALLAGHER: That's why I wanted to make sure we had enough time.

CHAIR SHACK: We can run a little bit over schedule --

MR. GALLAGHER: Okay.

CHAIR SHACK: -- if it comes to that.

MR. GALLAGHER: Okay. So let me turn it over to Stan and he will go through the stress evaluation.

MR. TANG: Okay. We did the stress analysis. First, we analyzed the individual load cases. In this case, we did 16 load cases, which including the pressure, thermal, dead weight seismic, seismic end movement, flooding and refueling.

And then we applied the boundary conditions onto the model. As we discussed before, these boundary conditions are at the bottom of the drywell embedded regions at the vertical constraints on the vent headers and also circumferential constraint at the star-truss elevations.

Okay. And then the load combinations are performed through post-processing of adding all the individual load cases that required for each load combinations.

The ASME Code Evaluations consist of make sure that the stress is meeting the stress allowables and also we have to look into the fatigue. And also one additional thing that we did look at is the areas reinforcements for penetrations.

CHAIR SHACK: Did you do any -- essentially, the thinning analysis in the thin region, that meets all the code requirements for thin sections, as we would do for a fact analysis?

MR. TANG: Yes. Yeah, we look into each bay region to make sure that the stresses in those three regions are --

CHAIR SHACK: Okay. Based on that thin shell analysis?

MR. TANG: Right.

CHAIR SHACK: Okay.

MR. TANG: Um-hum. So the slide -- okay, yeah. And this is the typical membrane stress intensity contour plot for the mechanical and live loads. Essentially, the stress intensity is small, except some localized regions, which have high stresses.

Next slide, 70. This is the typical membrane stress intensity contour plot flooding conditions. The highest stresses region is at the sandbed regions between the vent pipe and the concrete floor.

The ASME Code Evaluations, we did it for refueling load combination, which is Level A/B, and post-accident flooding condition, which is Level C. We used ASME Code Section III, Subsection MC, 1989 Edition, up to and including the Winter 1991 addenda. And we look at the four different stress category, which is: Primary membrane; primary membrane plus bending; primary plus secondary; primary plus secondary and peak stresses.

The drywell is divided into components for code evaluations and all components meet Level A or B and Level C allowables. Fatigue evaluation was done per NE-3221.5(d), which provides a list of requirement for extension in performing a detailed analysis. Oyster Creek satisfied all the requirements, as stated, in the NE-3221.5(d), that fatigue detailed for evaluation is not required.

Also, the area of reinforcement for

penetration evaluated per NE-3330 and if find that they all meet the area of reinforcement requirements.

72 is a summary table for ASME Codes. 74, okay, all right. So stress analysis of the drywell shell was conducted in accordance with ASME Code and SRP, Standard Review Plan, Section 3.8.2 using reduced shell thicknesses.

Stress limits are in accordance with the ASME Code requirements. The analysis shows that the drywell shell meets ASME Code stress requirement considering all design basis loads and load combinations.

MR. GALLAGHER: Okay. With that, we'll get into the base case conclusion and the sensitivity. And the section with sensitivity is rather short, because, essentially, what we did is it was the entire model was run with just the one change and we did two sensitivities. And John will go into all that. So, John?

MR. O'ROURKE: John O'Rourke from Exelon. So we have discussed the modeling of the drywell. We have discussed the buckling and stress analysis. I'm now going to go through the base case analysis results.

On Slide 76, Table 8-9 in the Base Case

Summary report shows the resulting safety factors for the refueling and flooding cases. As you can see, the safety factors in all cases exceed the Level A/B or the Level C allowable values, as shown in the tables.

And you see the -- Mike previously reported the sandbed limiting Bay 3.54, 2.02. He also mentioned that the cylindrical shell of 3.39 is more limiting. The other values were higher.

Moving on to Slide 77, this slide addresses the issue contained in our September 9th submittal wherein we noted that a simple finite approximation had been made in the base case analysis to use elevations versus arc lengths in the determination of the capacity reduction factor.

This slide shows in the upper corner here, this is the table that I presented on the previous slide, which just shows the base case results. And these are based on the capacity reduction factors using the elevation differences between the lines of support. And that is shown in this figure here. So these differences here for the middle, lower and sphere and the sandbed, the elevation difference used was 36 inches, which is the vertical distance between the floor and the upper beam support.

MR. GALLAGHER: For 396, John.

MR. O'ROURKE: 396. What did I say?

MR. GALLAGHER: 300. You said 36. 396.

MR. O'ROURKE: Sorry. That would have made a big difference, wouldn't it?

MR. GALLAGHER: It would make a huge difference.

MR. O'ROURKE: Thank you. 396 inches and then for the upper spherical region, the number is 156 inches between the upper beam support and the next level of support. So that's what was input to the base case analysis.

Now, as we mentioned, as Mike mentioned, in preparing for this meeting, we had Dr. Miller review the base case analysis report. And based on his comment that using arc lengths would yield a more accurate result, we had Structural Integrity recalculate the safety factors to quantify the amount of conservatism that the -- using the simplifying approximation of elevations produced.

And those results are shown right next to it. So the similar table to what is included in the base case report, up in the upper right hand corner, will give you the results using the arc lengths shown in the figure right below it.

So in addition to using arc lengths, we --

Dr. Miller recommended that we include the lower beam support, because it does provide stiffening and, therefore, changes the arc lengths. So as you can see in the figure to the left, there is no lower beam support shown here. And the elevation difference becomes 396.

When you include the lower beam support, which is this lower line of support, then you basically divide that area up into two pieces, such that the lower sphere and sandbed have an arc length of 235 inches and the middle sphere has an arc length of 332 inches. The upper sphere then has an arc length of 242 inches.

And when you input those into the analysis, and I want to mention that all of these safety factors are generated through post-processing, so this assumption did not require us to rerun the finite element analysis, so all of the stresses that Stan discussed and everything is unchanged by this simplifying approximation.

Okay. So all we are doing here is giving you a quantification of the simplifying approximation to show you that in all but the upper spherical shell cases, that, in fact, the approximation is conservative. Okay.

If you look at the values in the upper table, you can see -- well, the cylinder, of course, is unchanged, because elevation and arc length are the same, right? The vertical distance, right. So the upper sphere is the area that goes down from 4.27 to 3.45 for refueling and from 7.56 to 6.60 for flooding. You know, still well-above the minimum.

In all the other areas, the middle sphere, the lower sphere and the sandbed, you can see that by using the lower values, including the lower beam support and using the lower arc length numbers versus the 396 elevation difference, that, in fact, the safety factors show a slight increase. So indicating that, for the most part, the base case analysis is conservative.

I would like to move on to Slide 78 to summarize our conclusions for the base case analysis. We believe that we have been successful in creating a realistic, but conservative, 3-dimensional finite element model for the Oyster Creek Drywell. We think the model was used -- was analyzed using accepted industry practices and methodologies. And that the analysis demonstrates that the drywell has margin to the ASME Code.

At this point, I would like to summarize the results of the two sensitivity analyses that were submitted to the NRC on January 22, 2009. As Mike mentioned, the model that we used for this analysis was the exact same model that we used for the base case analysis with two exceptions, and those were the two exceptions that formed the sensitivity studies.

For Sensitivity Case 1, the thickness of the 51 inch locally thinned area in Bay 1 was reduced by 100 mils, while we kept the general area of the bay constant.

And then the second change was for Sensitivity Case 2, we kept the thickness so that we reduced the thickness of the general bay in Bay 19 by 50 mils, while keeping the locally thinned area constant.

Now, our purpose in selecting these cases was not only to address the commitment, which was to perform sensitivity studies to determine the degree to which uncertainties in the size of the thinned areas affect code margins, but also we only wanted to make one change in -- for each case, so that we could see the impact of that change.

There are, obviously, numerous combinations of changes that you could make in the sensitivity studies, but what we felt was that if we look at just changing a locally thinned case and see what the impact is on the results for that, and then looking at the change for a general area, which we don't expect degradation in the general area, but just to look at the effect, they -- both of them provide bounding conditions that we can possibly use later.

That was the reason for just making the one change. We selected the 100 mil change in the locally thinned area to bound the lowest external reading that we measured, which was a 602 reading in Bay, I think it was, 13. So by reducing the locally thinned area from 696 to 596, we have bounded that condition.

And we selected the 50 mil reduction in the general area thickness to bound things like standard errors, measurement errors, uncertainties in the size and thickness of previously corroded areas and any hypothetical 2 mil per year corrosion rate, should it occur. We don't expect it to occur, but should there be any, you know, we have got a bound on that. So that was the rationale behind the two sensitivity cases that we looked at.

And then on Slide 81, this slide was shown earlier and it basically compares the results of the base case, the limiting bays in the base case, the

3.54 and the 2.02 with the sensitivity cases. You can see that there is very small reductions in the safety factors as a result of making fairly large changes in either the general area or local area.

And our conclusion from the sensitivity cases is that by reducing the local thinned area by 100 mils, that we have bounded any uncertainties in the size and the thickness of local areas by reducing the general area by 50 mils, we have bounded in the uncertainties in the general areas thickness measurements. And although the safety factors are slightly reduced, the results of both sensitivity cases demonstrates safety factors above code minimums.

Finally, the sensitivity cases demonstrate that significant thickness changes could occur or measurement uncertainties could exist without a significant reduction in the margin to ASME Code specified safety factors. And that concludes the summary on the safety factor -- excuse me, the sensitivity cases.

MR. GALLAGHER: Any questions on that? So then if you go to Slide 84, this is how we began, which was the overall conclusion. And I won't go through and read it again, but it just summarizes the conclusions.

CHAIR SHACK: I just -- could I ask perhaps Dr. Ku, it's a little curious to me that the limiting cases in Bay 3 where in Bay 1 I have thinner regions, both above the 11-0 region and below it and I have a big thin region, that my limiting buckling is in Bay 3. And that seems like a curious result.

MR. GALLAGHER: Yeah, Stan?

MR. TANG: That is because in the flooding conditions, the loading is directly --

MR. GALLAGHER: No, it's the refueling conditions, Stan.

MR. TANG: I'm sorry.

MR. GALLAGHER: This was the issue that the -- Dr. Shack is pointing out that if we go to the table on page 81 --

MR. TANG: Um-hum.

MR. GALLAGHER: -- that like say for the refueling condition, the limiting location is Bay 3. Let me make sure I get your question right, Dr. Shack, because I think I understand. So why was Bay 3 limiting, because that's one of the more thicker bays?

CHAIR SHACK: It's one of the thicker bays. And I've got a much thinner bay right next door and it's not limiting and it just seemed puzzling to me.

MR. TANG: It is because the symmetric load coming up from the top from the lower beam supports, because the lower beam support, as you remember, it's not symmetrics. You know, the spacing is not symmetric.

CHAIR SHACK: Symmetric.

MR. TANG: Yeah.

MR. O'ROURKE: We did show that in an earlier figure if you want to refer back to that.

CHAIR SHACK: No, no, I --

MR. O'ROURKE: Okay.

CHAIR SHACK: When you mentioned it, I sort of forgot that was in there. So that brings in an asymmetry that is --

MR. GALLAGHER: Right.

CHAIR SHACK: Okay.

MR. GALLAGHER: Okay. So again, our conclusion slide is page 84, which is where I started, and that concludes our presentation. Are there any other questions for us?

CHAIR SHACK: Well, you know, as you say, sensitivity results in a way are always unsatisfying, because, you know, why did you pick these two? But I mean I felt one argument for picking Bay 1, you would get a complete reduction in the least constrained thin area, you know, in the Bay 19 and Bay 17, those are part -- those are up near the vent header reinforcements.

MR. O'ROURKE: True. But the theory behind that was I picked the largest circle, the 51 inch, and then the smallest, the thinnest area of the largest circle, which was, I think, pointed out earlier that that --

MEMBER ARMIJO: Largest, thinnest?

MR. O'ROURKE: Largest, thinnest, thank you.

MEMBER ARMIJO: And you did it some more.

MR. O'ROURKE: And then we thinned it by 100 mils. You know, that was my theory on picking that particular bay. And on the general bay, it was I wanted to pick a bay that was thin, 826, but that didn't have a thick bay next to it that would provide some additional support for it. I wanted to make sure that we got a good read on what the impact was of thinning the entire bay.

As I said, I think that's strictly hypothetical, that we would never get to a condition that where we would thin an entire bay, you know, for that. But just to see what the effect was, that's why I chose that particular bay, because it was -- it had thinner bays on each side.

MEMBER ABDEL-KHALIK: Just a sanity check again. What was the calculated maximum displacement in these two cases? For the base cases, the two different.

MR. GALLAGHER: The calculated maximum?

MEMBER ABDEL-KHALIK: Displacement.

MR. GALLAGHER: The displacement. Stan?

MR. TANG: I don't have that number now. I need to go back and check.

MEMBER ABDEL-KHALIK: I mean, is it in the order of 10s of inches, inches, mils?

MR. TANG: I don't think it is in order of 10 or 100.

MR. GALLAGHER: Are you talking about the displacement of the shell?

MEMBER ABDEL-KHALIK: Right.

MR. GALLAGHER: Francis, do you know?

MR. KU: I don't know.

MEMBER ABDEL-KHALIK: No, no, I'm talking about the base case. How much displacement do you have?

MR. O'ROURKE: Do we have a table for that, Stan?

MR. TANG: Ah --

CHAIR SHACK: But this is a buckling analysis, right? The displacement is actually indeterminant.

MR. TANG: Yeah.

MR. GALLAGHER: Marcos, do you know? Marcos? Marcos?

MR. HERRERA: Yeah, Marcos Herrera, Structural Integrity. For the buckling analysis, this is an indeterminant. But maybe for the ASME Code evaluation --

MEMBER ABDEL-KHALIK: Right, right.

MR. HERRERA: -- for the ASME Code, excuse me, evaluation you could provide those displacements.

MR. TANG: Actually, actually, I saw it right here in the report. If you look at --

MEMBER ABDEL-KHALIK: Just an order of magnitude.

MR. GALLAGHER: Yeah, just give --

MR. TANG: It's less than .1 inches.

MEMBER ABDEL-KHALIK: Less than .1 inches. Okay. Thank you.

MR. TANG: In the figure that I'm looking at. So you could say that is in the order of less than 1 inch, yes.

MR. GALLAGHER: Okay. Other questions?

Well, again, that concludes our presentation then.

CHAIR SHACK: Okay. I would like to take a break at this point. I think we'll come back at 10 of.

(Whereupon, at 2:34 p.m. a recess until 2:51 p.m.)

CHAIR SHACK: We can come back into session. Our next is the NRC staff review of this analysis and I assume that Brian Holian will kick us off.

MR. HOLIAN: Okay, thank you and good afternoon. My name is Brian Holian, Director of the Division of License Renewal. I'll just to brief introductions and then I'll turn it over to Louise Lund for some additional introductions and some opening comments.

I would like to highlight some other members of the NRC staff in the audience that have been involved in this review. First, my deputy in license renewal, Dr. Sam Lee to your right. We also have in the audience Donnie Ashley, a senior project manager, and David Pelton, a branch chief in license renewal.

Also, from the region today we have Mike Modes, the senior reactor inspector from Region I, who led the team and most recently was out there looking at the sandbed region. And I think one of his individuals talked at the subcommittee earlier who had been in the sandbed region.

Also, from OGC, I just don't often recognize them, but Brian Harris, one of the counselor from OGC, and Mary Beatty who is not with us today have also posed tough questions to the staff to help finalize our review throughout the processes.

With that, I would like to turn it over to Louise Lund. I recognize Louise. She is a materials engineer. Prior to her 13 years or so at the NRC, she worked at one of the national labs as a research scientist. She has been in license renewal probably the longest and has seen the long review of Oyster Creek as the project -- as the branch chief. I'm sorry branch chief overseeing the entire Oyster Creek License Renewal review and this is a significant part of it.

Louise, one other item I would just like to mention. She is within a month here of graduating from the SES Kennedy Development Program, so she will enter the SES here in a month. With that, I'll turn it over to Louise.

MS. LUND: Okay. Thank you. Whoops,

maybe I can turn on the microphone. As Brian said, I'm Louise Lund. And I was the branch chief for the Oyster Creek License Renewal review. And I think as you probably know, Oyster Creek Nuclear Plant was relicensed on April 8, 2009 for an additional 20 years of operation.

And during the license renewal review, Exelon had the opportunity to brief the ACRS Subcommittee and Full Committee regarding their aging management strategy for the drywell shell. And I know that you have seen that they drywell shell has been evaluated extensively through three different analyses.

There is a conservative bounding analysis which has been discussed a little bit today. It was reformed in the early 1990s by General Electric, which remains the current licensing basis for the plant. During the license renewal review, the staff contracted with Sandia to perform a confirmatory analysis and I know the Committee was also briefed on that review as well.

During the license renewal briefings with the ACRS, Exelon further committed to perform a 3-D analysis to better quantify the margins above the ASME Code minimums. That commitment was made a condition to their license and Exelon filled that commitment by submitting an extensive summary report of their analysis on January 22, 2009, which you were provided.

An addenda to the report was received earlier this month and the ACRS Committee was asked to be briefed on the results of this analysis, which brings us to the briefing today. The staff has performed their review of the 3-D analysis as part of the commitment inspection for license renewal.

The inspection report was issued on May 12, 2009. The inspection interval for the drywell shell had been the subject of an evidentiary hearing. The staff's review followed the direction given by the Commission's April 1, 2009 order that addressed the intervenor's appeal and directed the staff to move to relicense the plant.

The issue that was in hearing is now on appeal to the Third Circuit Court. So now, I would like to briefly introduce the staff presenters. And to my left is Dr. Allen Hiser, who is the senior level staff for the Division of License Renewal. And to his left is Kamal Manoly, who is a senior structural engineering -- excuse me, he is the senior level staff for the Division of Engineering in the structural area. And then Hans Ashar, which is to his left, who is a senior structural engineer, who was in the Division of Engineering and is now a rehired annuitant helping us in the Division of License Renewal.

What I would also like to mention, too, is that the experience that both Hans and Kamal bring to this review is 35 years of structural engineering experience in nuclear power plant applications. And Kamal has 40 years of experience, including 37 years in nuclear power plant applications. Both engineers represent the NRC and a number of organizations that develop standards, including the ASME Code, the American Concrete Institute and the American Institute of Steel Construction.

And Hans is a fellow member of the American Concrete Institute in the American Society of Civil Engineers. So that's just to give you a little bit of background.

And to lead off our discussion today, Dr. Hiser will be making a presentation. Thank you.

MR. HISER: Thank you, Louise. Good afternoon. Let's maybe flip to Slide 2. What I want to do today is in combination with Kamal is go over three main areas. One is to provide an overall perspective of the Oyster Creek Drywell shell, discuss, not in too much detail, the analyses that have been performed previously. There has been a lot of discussion of the GE analysis, the Sandia analysis. I just want to provide some perspective on how this recent analysis fits in with the prior analyses.

Then we will talk a little bit about the review that the NRC has performed of the Sandia 3-D finite element analysis and Kamal will go into detail on the staff review and staff conclusions on that.

CHAIR SHACK: You said Sandia. You mean Exelon?

MR. HISER: Exelon, yeah. The Structural Integrity, I'm sorry.

CHAIR SHACK: That's all right.

MR. HISER: As has been described, corrosion was first identified in the Oyster Creek Drywell liner in the late 1980s. As illustrated by one of the figures shown by Exelon, it is really a fairly narrow band of the drywell shell overall that has experienced corrosion in the sandbed region. And it is prevalent in about half of the bays.

Remediation at that time was implemented by, first of all, changing the geometry, removing the sand, so that water could not be held up against the liner. And a very robust submersible quality coating, and it's a three layer coating, was applied to ensure that water could not get to the carbon seal liner.

Ultrasonic measurements, at that time, were fairly extensive. I believe it is at least 1,000 measurements that were made, at that point in time. There has been a very fairly extensive continuing program of monitoring and there is a continuing program that Exelon will be implementing. So the condition of the liner should be fairly well-understood for the areas monitored and will be into the future.

And I guess one point, no additional corrosion has really been identified since the early 1990s when the coating was first applied.

Now, we have heard a little bit about the analyses that have been performed. Just to hit some high spots, the General Electric analysis that was performed in the early 1990s after the corrosion was first identified is a conservative analysis. It assumes a uniform reduction in the shell thickness to the minimum measurement and the locally thinned area that is two-tenths of an inch less than that.

It does use the modified capacity reduction factor, which Dr. Miller discussed earlier, and that applies to the refuel load condition only. This is the current licensing basis. It is a conservative analysis consistent with what we see and what I'm sure the Committee is used to seeing with many conservative assumptions made.

Now, the Sandia analysis was sponsored by the NRC as a part of the license renewal review of the Oyster Creek application. Similarly, it implemented conservative modeling of the degradation and because of the unavailability of proprietary design information, Sandia made numerous conservative assumptions on geometry and other factors.

In the case of the Sandia analysis, they used the unmodified capacity reduction factor. They did not have access to some of the support data that supports the modified capacity reduction factor. That again was for the refuel load condition.

The Sandia analysis --

MEMBER ABDEL-KHALIK: Now, if I remember correctly, the General Electric analysis, which is the current licensing basis, is not a full 360 degree analysis. It is one-tenth of the angular range. So it is an 4 inch slice, if I may, which is one-tenth. Are you satisfied that -- with the current licensing basis?

MR. HISER: I believe that -- Kamal?

MR. MANOLY: Yes, we are definitely. I

mean, the --

MEMBER ABDEL-KHALIK: Based on?

MR. MANOLY: Modeling. In terms of the modeling of the --

MEMBER ABDEL-KHALIK: Even the asymmetry that we heard about, would you still consider a one-tenth or 360 or 36 degree segment analysis to be adequate?

MR. MANOLY: For this particular case, yes, definitely.

MEMBER ABDEL-KHALIK: Okay.

MR. HISER: Okay. And then as described by Exelon this morning, their 3-D finite element analysis was part of a commitment that they made to the ACRS and more formally to the NRC. It was intended as a realistic analysis to quantify the margins above the ASME Code requirements.

And one point I would make is in both the General Electric and the Sandia and the SIA analysis, there really are no concerns that the margins do not meet the code. The purpose of the SIA analysis was to provide a quantification of how far above the margins really are.

It is intended as a realistic, but reasonable, analysis. It does not have conservative assumptions for all of the parameters that are included in the analysis, that's by design. It's not intended as a conservative analysis, but as a realistic analysis.

As you have heard earlier today, the SIA analysis included a base case --

CHAIR SHACK: Well, let me just -- you know, unless you are going to include a genuine study of uncertainties, the realistic case, you know, needs some quantification, at least some way to address uncertainties, which includes adding conservatism where you can't really quantify the uncertainties any other way.

MR. HISER: Yeah, there is a conservative bias to the analysis overall. But, for example, with the thicknesses of the bays, it is not a bounding interpretation of the --

CHAIR SHACK: Data?

MR. HISER: -- corrosion. I mean, there is a more realistic approach that is taken in that.

MS. LUND: This is Louise. You know, especially in comparison to the General Electric analysis where you uniformly send it to .736 where, you know, I think we can all agree by looking at the data that didn't really represent the physical condition of the shell. So I think that this one is certainly more conservatively bias, but hopefully towards the realistic end. We were trying to understand, you know, the margins better, you know, about the code minimums.

MR. HISER: All right. In this case, the SIA analysis did include the base case as well as the two sensitivity cases, which gives some indication of, you know, regarding measurement uncertainties and the possibility of general corrosion, what the effects would be on the safety factors.

The SIA analysis did have access to GE proprietary data, so it has actual values instead of having to make conservative assumptions, which was the case for Sandia. And the SIA analysis did use a modified capacity reduction factor again for the refuel load condition.

And I guess the bottom line is that all three of these analyses, the first two, which are highly conservative, the last which is realistic, but conservatively biased, all demonstrate that the Oyster Creek Drywell shell exceeds ASME Code margins.

Turning to the next page, we have three analyses. Each of these analyses has also had an independent review conducted on it. For the GE analysis, the NRC contracted with Brookhaven National Laboratory to review the analysis and it was found to be acceptable by Brookhaven and was accepted by the NRC as the current licensing basis for Oyster Creek.

The Sandia analysis was actually reviewed by ACRS three years ago as a part of the license renewal review. And the ACRS has some fairly strong statements on the adequacy of that analysis.

For the SIA analysis --

MEMBER ABDEL-KHALIK: Now, the capacity reduction factors will respond to a maximum allowable deviation from the ideal geometry. And I guess the point was made that this particular shell was shown to meet those requirements at the time of construction. Is that true? I'm sort of asking the Region I inspectors.

The question is the analyses and the capacity reduction factors that are used in the analyses correspond to a maximum allowable deviation from the ideal spherical geometry? And the statement was made that this is done only once at the time of construction. And the question is has that indeed been the case?

MR. MODES: If you mean by has it been the case, was it done at the time of construction?

MEMBER ABDEL-KHALIK: And whether, indeed, it meets those criteria --

MR. MODES: Okay. I understand the question.

MEMBER ABDEL-KHALIK: -- classified in the code.

MR. MODES: Now, obviously, I wasn't present when that was done in the '70s.

MEMBER ABDEL-KHALIK: I understand.

MR. MODES: Right. However, the process of handing off, if you will, from Section III or Code construction to Section XI real-time analysis, requires a certification by both the user of the code and as reviewed by the NRC that all those conditions are met. So it has been certified and reviewed by the Agency.

MEMBER ABDEL-KHALIK: And this analysis is based on the unloaded condition. Is that correct? That whatever deviation from the ideal spherical geometry is based on the unloaded geometry.

MR. MILLER: The correct -- Clarence Miller. You are referring to the loads, but it is -- the loads are applied, but the geometry is assumed to be a true spherical service without any deviations from theoretical shape.

MEMBER ABDEL-KHALIK: Right. My question is the deviation from the theoretical shape is when the thing is constructed piece-wise or after the thing is completed and loaded?

MR. MILLER: Okay. I understand what you're saying now. It is after construction, not after loadings are made.

MEMBER ABDEL-KHALIK: Okay. Thank you.

MR. HISER: All right. Now, with the recent Exelon 3-D finite element analysis performed by Structural Integrity, the State of New Jersey had Becht Nuclear Services perform a review of the report. And they identified areas of non-conservatism, areas of additional conservatism. Their conclusion was that the analysis was a realistic and reasonable analysis.

So sort of the summary there is that all three of the reviews pointed to the conclusion that Oyster Creek Drywell shell can perform its intended function without compromising the ASME Code margins.

If we go to the next slide, Exelon then described a January 22, 2009 submittal which provided the base case and sensitivity case results for the 3-D finite element analysis. In addition, there was a September 9, 2009 submittal that provided an addendum to that report.

Now, the staff review of the January 22nd submittal had several pieces to it. One was a detailed review of the paper submittal provided by Exelon. In addition, we performed an inspection of proprietary calculations that supported the report and that was as a part of the license renewal inspection. I have indicated there and I believe Louise provided information as well about the inspection report that summarized the staff review.

In addition, the staff issued a staff assessment of the 3-D finite element analysis and the ADAMS number is provided there.

Kamal will go into more detail on the individual pieces of the staff review and the staff findings.

Now, the September 9, 2009 submittal, as described earlier by Exelon, involved two modeling approximations that were suggested to them by Dr. Miller. And upon receipt of this submittal, the staff did a detailed review of the September 9 submittal. We did perform an audit last week, again, trying to focus on the proprietary calculations that that supported the submittal and we will be issuing an audit report in about the next month that will summarize our -- the audit that we performed and our findings in that audit.

I guess with that, I'll turn it over to Kamal.

MR. MANOLY: I'm Kamal Manoly, Division of Engineering at NRR.

CHAIR SHACK: Microphone.

MR. MANOLY: I'm Kamal Manoly, the Division of Engineering at NRR. And I'm going to go over the summary of our review of the 3-D finite element model, basically, the highlights of our review and, essentially, you heard the detailed version from the Exelon this morning. And I think, in general, our audit that was done of the inspection effort supported the conclusions that they have reached.

And our report is in the public record, basically, it's a detailed summary of what I'm going to be talking about here.

In the finite element model, basically, the highlights of the -- five bullets I provided. The first is the model provides realistic estimate of the current condition of the drywell, including evaluation of the effects due to the measurement uncertainties.

The model represents the degradation considered anything local in the areas and identified in '92 inspection prior to the application, the epoxy coating and the exterior -- to the exterior of the sandbed region. And these measurements were confirmed in some sequence exam -- inspections in '94, 2006 and 2008. So the conclusion is that there is no trend of degradation past '92.

The side thickness in all bays and the sandbed area correspond to the UT measurements taken in 2006 inspection and confirmed in 2008. The 3-D finite element model incorporates the penetrations larger than 3 inch diameter, insert plates, reinforcing plates and stabilizing star-truss assembly, vent lines and many connections to the dry well.

And the last point is that the model, as we heard earlier this morning, contains 406,000 elements, that's an extensive model. Typically we don't see that very often in any licensing reviews.

MEMBER BANERJEE: Have you seen it in any?

MR. MANOLY: Not -- give me one second. The benchmarked it to -- you know, the conversion of 2000 a million elements, so that's more than I really have seen in my experience. It has element sizes from 3 inches down to .75 inches in the locally thinned areas, which is very, very fine mesh.

MEMBER ABDEL-KHALIK: Now, with regard to the fourth bullet on your slide.

MR. MANOLY: Um-hum.

MEMBER ABDEL-KHALIK: Do you understand the statement made by the applicant's consultant that for the buckling analyses the vent lines were not loaded?

MR. MANOLY: Well --

MEMBER ABDEL-KHALIK: What does that mean from your perspective?

MR. MANOLY: -- the vent -- if you have a vent line, and it has -- I mean, you're talking about the loading on the vent line itself? Okay. The purpose of this analysis is to determine the margin in the drywell. And it's not intended to determine the-- whether the vent line will buckle or not.

Now, we know both lines are basically a pipe. The buckling loads for a pipe is really not going to be as critical as for a shell. So I don't expect the pipe to fit in buckling before a shell. That's my short answer.

Now, we could have modeled this thing with, like they said, applying a stiffness matrix at all locations to simulate the flexibility of the connections.

MEMBER ABDEL-KHALIK: I mean, I don't

truly understand what it means when you say that the vent lines will "buckle." In a sense, these things are oriented differently.

MR. MANOLY: Yes.

MEMBER ABDEL-KHALIK: So what does it mean when the applicants say that for this vent -- for this buckling analysis, the vent lines were unloaded? What does that mean?

MR. MANOLY: No, I don't think -- okay. They applied the loads on the whole structure, including the vent lines. But they didn't do buckling analysis -- evaluation on those connections, on the vent lines. Now, why do we need to do a buckling evaluation on a pipe because I don't think it's -- the pipe is not going to fill in buckling before a shell.

MEMBER ABDEL-KHALIK: Again, that's not the point. Because I would not expect them to buckle in that orientation.

MR. MANOLY: Right.

MEMBER ABDEL-KHALIK: The question is whether waste failure, how is failure of this structure defined?

MR. MANOLY: Failure is not -- well, failure -- you're talking about not meeting the ASME code limits?

MEMBER ABDEL-KHALIK: Right.

MR. MANOLY: Well, it's for stress or for buckling. I mean --

MEMBER ABDEL-KHALIK: Oh, no, I don't mean --

MR. MANOLY: Yeah, yeah.

MEMBER ABDEL-KHALIK: Right, right.

MR. MANOLY: That's failure.

MEMBER ABDEL-KHALIK: Right.

MR. MANOLY: That's correct.

MEMBER ABDEL-KHALIK: And in your analysis or evaluation of the applicants, you indicate that under no condition will these vent lines actually fail.

MR. MANOLY: Not -- under the loading conditions that were evaluated, we would not evaluate in the vent lines whether they meet ASME Code limits or not, because this was already designed, accepted part of the original design. So the only thing that can come to mind is that do they fail in buckling? I don't think they would, because pipe in general would not fail in buckling before a shell. That's -- so they didn't evaluate the stresses, because evaluation of the stresses in the vent lines was not part of this assessment. It was accepted as part of the original design of the plant.

MEMBER ABDEL-KHALIK: Okay. Thank you.

MR. MANOLY: Okay. The next slide about the modeled boundary conditions. Again, the boundary conditions in the analysis realistically capture the restraint offered by the concrete in the radial direction. And the spherical -- for the spherical segment of the drywell below the bottom of the sandbed area would all the free displacement in the meridional direction.

So this -- they're not taking advantage of any friction between the two. And the spherical segment above the bottom of the sandbed area, no credit was taken for the restraint caused by the concrete as is mentioned.

The drywell displacement is realistically constrained in the circumferential direction by the 8 star-truss because the connections provide that restraint from rotation around the vertical axis.

The next slide is on the input loading. The evaluation was performed for the conditions that capture the combinations consistent with NRC approved update and the modifications to the original FSAR from the plant. These include the refueling and post-accident conditions.

The next slide on the stress evaluation. The stress evaluation was performed according to ASME, Boiler & Pressure Vessel Code, Subsection NE, Class MC component, which is not the licensing basis originally, and Section VIII vessel, but was evaluated to 1989 ASME, including the 1991 Winter Addenda, in lieu of the original design to 1962 Section VIII.

We found that to be acceptable, because we endorsed ASME in the regulations. And it was evaluated to provide the stress intensity limits at different operating conditions or limits for the local membrane stress due to thickness reduction from local or degenerative corrosion effects.

The refueling case were primed to be the limiting load combination in Level A and B condition while the post-accident flooding case was limiting for Level C service condition.

As we're going to see later and the applicant -- licensee mentioned that using Level C limits are the conservative for this condition, because it really is a Level D limit.

Material allowable stress values were not available, such intensity were not available for the material, they developed it from the rules provided in Appendix III to ASME Code Section III.

And the last item on this slide is that the fatigue evaluation of the drywell shell according to ASME NE and was also acceptable.

The next slide we move to the buckling evaluation. The buckling was performed to ASME Section III, Subsection NE-3200 and the Code Case N-284-1, which we had endorsed in the regulations. I mean, the Code case is endorsed in the Reg Guide 1.84.

The minimum factor safety is 2.0 for Levels A and B, as you all know, and the 1.67 for Level C, which we consider conservative since the loading condition really pertains to Level D.

The factor of safety is calculated based on the buckling stress value determined from the classical analysis and used by appropriate capacity reduction factors as Dr. Miller mentioned. That counts for the imperfections and non-linearity in the geometry and the boundary conditions as well as non-linearity and material properties.

Where applicable, the CRF was modified to account for the benefit of the hoop tensile stress in the shell as a result of the weight of the water in the reactor cavity pool, which produces hoop tensile stress in the vessel.

The refueling load cases for the buckling evaluation are refueling and post-accident flooding load cases. We have seen the summary of the factors of safety, basically, for the refueling load case. The minimum factor of safety 3.39 in the cylindrical region and 3.5 in the spherical region were both compared against a minimum of 2.0.

In the flooding case, the minimum factor of safety was 3.46 in the cylindrical region and 2.0 in the spherical region against a minimum factor of safety of 1.67.

The next slide we will talk about the sensitivity analysis. And as we heard already, they have done two cases. One where they thin the corroded area by 100 mils from 696 to 596, which is fairly conservative, I believe. And in the other case, S2, they thin the wall thickness, the general area, in Bay 19 by 50 mils from 826 mils to 776 mils while keeping the local thickness in the area the same constant as 720.

If we look at the change in the factor of safety in both cases, S1 and S2, the reduction is fairly small, about 8 percent, which tells us that even with that kind of sensitivity analysis you really haven't gotten much reduction in there. So you need a lot of thinning in the shell to get anywhere close to the limits of 2 or the 1.67.

The next slide talks about the -- what we found to be the conservative assumptions that were made in the analysis. The bounding seismic response spectra at the location of the star-truss, they use the bounding response spectra, not the -- usually analysis you can model the response spectra at different elevations, but they use the bounding response spectra at the star-truss for the whole -- for the entire seismic model, which is fairly conservative.

The other part that is in the post-accident flooding case, the weight of the water was included, the mass was added to the drywell, even though it could be divided between the drywell and the bioshield wall. They used the conservative 2 percent damping for the welded steel structures under OBE. Now, see now Revision of Reg Guide 1.61 has 3 percent damping for that condition.

For the post-accident flooding case, evaluated again ASME Level C as we mentioned where it could have been Level D.

Support provided by the -- at the eight locations by the star-truss is conservatively neglected from the analysis, especially in the buckling evaluation. That was --

MEMBER ABDEL-KHALIK: Now, with regard to that, what was the capacity reduction factor used for the case of the accident loading condition? And how does that value compare with the .207 value for the no internal pressure case?

MR. MANOLY: Which loading condition are you referring to?

MEMBER ABDEL-KHALIK: The accident loading condition.

MR. MANOLY: The --

MEMBER ABDEL-KHALIK: Where the --

MR. MANOLY: -- post-accident?

MEMBER ABDEL-KHALIK: -- safety limit, right, is 1.67.

MR. MANOLY: The factor of safety --

MEMBER ABDEL-KHALIK: Is 2 something.

MR. MANOLY: Yeah, around -- yeah. In the cylinder it's 2.0. It was 2.0 in the cylinder. This is 1.67.

MEMBER ABDEL-KHALIK: I'm asking you about the capacity reduction factor --

MR. MANOLY: Oh, capacity reduction factor.

MEMBER ABDEL-KHALIK: -- used in that

case. And how does that compare with the case with zero internal pressure, .207 theoretical value? And whether or not you are satisfied with the value of the capacity reduction factor used in that analysis.

MR. MANOLY: We are going to have to look at the -- we will have to look that up in the --

CHAIR SHACK: Yeah, they are typically around .4.

MR. MANOLY: Yeah.

MR. ASHAR: 3 something, but --

CHAIR SHACK: Well, you know, it varies from, you know, the cylinder. I'm looking at the refueling buckling and the cylinder. It's .47. Then in the sphere it's .44, .34, .32.

MR. ASHAR: Post-accident vary. For the -- in case of post-accident flooding, probably the -- I don't remember by heart, but it is --

CHAIR SHACK: .53, .49, .50.

MR. ASHAR: Okay. I hear you. Okay.

CHAIR SHACK: I'm reading it off of the table. I don't know it by heart, either.

MEMBER ABDEL-KHALIK: So I mean, the reason for my question is that uncertainties in that capacity reduction factor can potentially reduce the calculated value below the 1.67 limit. And therefore, it is important to understand whether or not it's justifiable to use whatever capacity reduction factor has been used in the analysis.

MR. ASHAR: Normally, I would say I would be concerned about that type of concern for refueling load case, because that is where the controversy arises is to the CRF. In case of post-accident flooding, there is a tour of bay side stresses produced by the load itself.

Okay. So when the stresses are produced, it is quite appropriate to use the -- Dr. Miller's formula to come out for the capacity reduction factors. .207 is the minimum when you do not have the help from inside stresses.

MEMBER ABDEL-KHALIK: I understand. I'm asking whether or not you have looked at that and evaluated the uncertainty in that capacity reduction factor and whether there are any circumstances in which the uncertainty in the capacity reduction factor would cause that safety limit to drop below the 1.67 value specified in the code?

MR. ASHAR: Well, I can tell you frankly that for post-accident flooding load, we did not see a need to verify that, because it is quite obvious the way the steps are there in calculating the factor of safety, you can't miss if there is anything wrong in that particular section.

For refueling load, I can understand you can look at the compressive stresses, inside stresses where they occur. Whether they are genuinely -- they can use it or not. But in case of post-accident flooding, the real stresses that we know is produced by the load itself. So we did not see the need. But we did type of investigation for refueling loading where we thought there was not much uncertainty.

MR. MANOLY: You could have variations in the capacity reduction factor in the post-accident, but the refueling -- in the case of refueling, you could have variation in the tensile stress. But for the flooding, it's there.

MEMBER ABDEL-KHALIK: So you are convinced that whatever capacity reduction factors were used in this analyses are, indeed, correct and/or conservative?

MR. MANOLY: For the post-accident flooding or everything?

MEMBER ABDEL-KHALIK: For all analyses.

MR. MANOLY: Yes, I mean, really no great objection to what has been -- audit was in the report. We did look into the various radiations, but we are satisfied that it has been done quite accurately, yeah.

MEMBER ABDEL-KHALIK: Okay.

MEMBER BANERJEE: I have a question of the last bullet. On the, yeah, size of the -- you call that a conservative assumption.

MR. MANOLY: Right.

MEMBER BANERJEE: Now, looking at the pictures, you know, we haven't seen the pictures of the areas themselves, but looking at the 10 region sort of the data that they showed us, I would have thought that it's also clear that they are conservative.

MR. MANOLY: I think I see your point. I think what is not clear here is that when they show points on the -- I think in the presentation this morning --

MEMBER ABDEL-KHALIK: The 51 inch.

MR. MANOLY: Yeah.

MEMBER BANERJEE: Yeah, it might have been more what was showing pictures of the corroded areas.

MR. MANOLY: I mean, an accident --

MEMBER BANERJEE: Maybe you can show us some.

MR. MANOLY: Um --

MEMBER BANERJEE: Well, we have seen them before, but this subcommittee keeps changing and so then you have different Members and all sorts of things.

MS. LUND: Can I take a stab at this? Okay. Because having looked at your -- you are right. I think that there has been a lot of information and pictures have been provided in the past. It would probably be very illuminating, but I think just to talk through what exactly happened, you know, when the water came into the sandbed where they really experienced more of that bathtub ring sort of corrosion was there at the water area interface.

So when they took out the sand and they looked at what -- you know, essentially the appearance of the corrosion, they could physically observe, you know, that -- this particular ring and the areas around it. You know, they blasted off the rust, you know. And they did all this characterization work. In fact, when Mike Gallagher was talking about these 1,000 measurements they did, they actually provided for the subcommittee four binders full of information.

I don't know if everybody remembers this, but there is some level diagrams, there is some diagrams which actually show you where they were taking all these different measurements to characterize what was going on. They actually took core samples, plug samples, core plug samples in order to tie the UT to this degradation.

So they did a lot of characterization work to look at, okay, where is it actually corroding the worst? Then what they did is they said, okay, if these areas that look like they are, you know, thinned the worst from the UT measurements and from the visual measurement, you know, the visual observations, they ground down those external points that they have used to trend to the future as well as those grids. And there is a picture actually in the -- one of the subcommittee presentations of the different grids and what they look like, you know, the 49 points that they were doing on the inside and doing on the outside.

So I think that there is -- as far as trying to characterize, when we make a comment such as the size of the locally thinned areas in the sandbed region are conservatively mapped, it's somewhat with the understanding too and looking back at these pictures, there is pictures also that show the coated surface. And you can look at these external points. And you can see where it is divotted. You can see where they have actually -- in the -- because the way that the outside of the shell looks with the corrosion, it's more like, I would say, an orange peel effect.

You know, when they ground down and look at the transducer flat against the shell itself, you can see where as the light hits the coating how it is divotted down. So you can see in looking at the different pictures we have had inspectors go in and look at it. We have kind of followed along in this process the whole way.

So I think that that kind of figures into our -- when we look at the individual points that are being trended going forward an understanding of what the system looks like, what the whole surface would be able to tell you.

MEMBER BANERJEE: Yes, but it's not consistent with the data they showed us.

MS. LUND: As far as that --

MEMBER BANERJEE: You look at the data.

MS. LUND: -- map, you mean?

MEMBER BANERJEE: Yeah. I would say that, you know, based on that data, it's not conservative. Just looking at it without looking at the pictures, I could draw larger areas.

MS. LUND: As far as are you talking about with the sensitivity analyses? Is that what you're talking about?

MEMBER BANERJEE: No, no, no, just the data they presented to us today.

CHAIR SHACK: Remember, they take another 100 mils off, so if you don't like the --

MS. LUND: Right.

CHAIR SHACK: -- 10 or 15 mils --

MS. LUND: Right.

MEMBER BANERJEE: Yeah. But I'm talking about the area, not the depth.

MR. MANOLY: Let me attempt to answer, because I -- that --

MEMBER BANERJEE: The answer you gave me is -- doesn't reassure me.

MR. MANOLY: No, let me clarify. The number that shows in the areas from different bays, I think that's what you are referring to there, don't quite match with the --

MEMBER BANERJEE: No.

MR. MANOLY: -- figures.

MEMBER BANERJEE: They don't.

MR. MANOLY: Yeah. And the reason is simple. Those numbers are kind of pits, whereas the general area is what thickness you see in here.

MEMBER BANERJEE: So if you look at say--

MEMBER ARMIJO: 29, Slide 29.

MEMBER BANERJEE: Yeah.

MEMBER ARMIJO: On the Exelon presentation.

MEMBER BANERJEE: That's what I'm looking at right now.

MEMBER ARMIJO: Right.

MEMBER BANERJEE: Yeah.

MEMBER ARMIJO: So that could be a big ellipse.

MEMBER BANERJEE: Right.

MEMBER ARMIJO: But then if you averaged all the numbers in, it probably would turn out to be different.

MR. MANOLY: What they did with that ellipse, they thinned an area theoretically that size by -- to 711. Now, the numbers you see here, these are pits and not generalized. This was generalized corrosion. I mean, these are measurements that represent the thicknesses.

MEMBER BANERJEE: The answer was given to us when we asked that. I mean, I'm used to, you know, oil/gas pipelines pit.

MR. MANOLY: Right.

MEMBER BANERJEE: We understand what pitting corrosion is.

MR. MANOLY: Right.

MEMBER BANERJEE: It basically needs water and some CO_2. Now, they told us it's not, it's more generalized, it's not pitting corrosion.

MR. MANOLY: Is that --

MEMBER BANERJEE: Was it pitting corrosion then?

MR. MANOLY: My understanding from discussion with the licensee that this is not generalized thicknesses in this area. These are certain location. The low point, but the general thickness of the shell is the -- what you see in these numbers.

MEMBER BANERJEE: So where there measurements made or is that just a visual observation?

MS. LUND: No, these are measurements.

MEMBER BANERJEE: Oh, these are measurements?

MS. LUND: These are measurements, right.

MEMBER BANERJEE: But in between, were there any measurements made or not?

MR. MANOLY: Well, those are numbers in

like Bay 15 that when you see the numbers, use 935 thickness, that is the average in that area.

MEMBER BANERJEE: So look at 711 in Slide 29. And then there is 715 on the left.

MS. LUND: Right. These are the external measurements. There is external measurements and there is internal measurements. And the external measurements were, as I said, pre-selected, okay, for the fact that the -- from the original characterization of the most thinned areas. And then they actually were biased even more by grinding them down to be even thinner.

So the -- that's why these measurements are -- this is where your -- there is a -- in fact, I can show you a picture of what one of them looks like.

MEMBER BANERJEE: That would be helpful.

MS. LUND: Around --

MEMBER BANERJEE: You can show us the Bay 15, that area, somebody has a picture?

MS. LUND: These are from -- this is from 2006. This is -- actually answers your -- one of your guy's questions about the way the coating looks as well.

MEMBER BANERJEE: This is B7, right? Yes, 15.

MS. LUND: You will also have internal measurements that are averaged, okay?

MEMBER BANERJEE: Yeah, we --

MS. LUND: Because there is a grid.

MEMBER BANERJEE: I can see those.

MS. LUND: Um-hum.

MEMBER BANERJEE: But they have actually-- the internal measurements, there are only two grids shown. One small and one rectangular.

MS. LUND: Well, you are talking on page 29? Is that the page you are looking at?

MEMBER BANERJEE: Slide 13 now I'm looking.

MS. LUND: Slide 13.

MEMBER BANERJEE: I'm trying to call it Slide 13, Slide 29 and trying to understand --

MS. LUND: Right.

MEMBER BANERJEE: -- why you would have that little circular area there instead of a big circular area.

MR. GALLAGHER: Dr. Banerjee?

MEMBER BANERJEE: That's all I'm trying to understand.

MR. GALLAGHER: Maybe I can help.

MEMBER BANERJEE: Yeah?

MR. GALLAGHER: Because Louise, Ms. Lund, is showing you some pictures that were shown. So if I can, I can just show you this. I'll walk over here in a minute and show you. But this is actually a package. This was called the reference material package that was from the January 18, 2007 meeting, okay?

And so that's on the record and that's, you know, you will have that available. But if you look at, say Bay 15 was the one that you were just asking about, this is the picture of Bay 15. I'll walk over here and show you in a minute.

MEMBER BANERJEE: Okay.

MR. GALLAGHER: And you can see one of the measurement points. So one thing I wanted to make sure was clear, you know, we -- when you look at this, we don't -- when we are in the sandbed, we don't see like a circle of thinness, you know, or anything like approximating that. As I said before, these external points were identified as -- when you run into -- when we went into the sandbed.

We were looking for thin areas visually and then we, you know, prepped them and then took data. And the purpose of that was to, remember at the time this was in 1992, confirm whether or not our interior grids were sufficient enough. And we confirmed that they were based on that, but we continue to monitor those individual points, because they are good indications of the thinnest of the thin locations, particularly since we ground them down.

So when you look at this Bay 15 where you said, hey, you know, could you have drawn like a, you know, big oval or something like that, you look at this and you won't see an oval or anything that approximates an oval visually. And so, you know, that's why we did not.

And the circles were just simply picked based on the previously evaluated methods which were squares or these trays and we just enveloped the whole thing. And then I think what the staff is saying, because we said it, that we think that these local thin areas are conservative, because when we assigned the value of the thickness to that local area, it was based on a very conservative -- we assigned the entire thickness of our conservative number. And we walked you through those numbers of how we did that.

MEMBER BANERJEE: I think I understand. And really I'm just questioning you to sort of confirm that they were truly conservative or not. And I think I don't completely understand the procedure as to how you made these little squares and things, but --

MR. GALLAGHER: So for instance, this is Bay 15 drywell shell.

MEMBER BANERJEE: Um-hum.

MR. GALLAGHER: This is a picture. And again, this is on the record.

MEMBER BANERJEE: Yeah.

MR. GALLAGHER: So see this divot right here?

MEMBER BANERJEE: Yes.

MR. GALLAGHER: That's one of the areas that were prepped for measurement. So that would have been identified visually as a small thin area and then it was interrogated. This is the general area, so that's why we're saying we had general corrosion. Okay?

MEMBER BANERJEE: How -- what's the scale there?

MR. GALLAGHER: Well, this divot is -- Pete, how big are those divots?

MR. TAMBURRO: These are --

MR. GALLAGHER: Go to the mike, Pete. Go to the mike.

MR. TAMBURRO: Pete Tamburro. The divots are between an inch and 2 inches. They are --

MR. GALLAGHER: Okay. So that's about a 2 inch scale right there.

MR. TAMBURRO: -- not large.

MEMBER BANERJEE: Okay. And so this is in the order of a foot or something?

MR. GALLAGHER: Well, probably more than that, because this is -- you know, curves this way, curves this way.

MEMBER BANERJEE: So it's corrosion over a fairly large area then?

MR. GALLAGHER: Correct, correct.

MEMBER BANERJEE: Yeah, as you would expect at the sand area interface. Close the sandbed?

MR. GALLAGHER: This particular -- so you can see, this area up here is relatively smooth.

MEMBER BANERJEE: Yeah.

MR. GALLAGHER: So this was probably near the top.

MEMBER BANERJEE: Okay.

MR. GALLAGHER: That area right there is relatively smooth right here.

MEMBER BANERJEE: Okay. So let's go back to this circle. That's slide 29. That circle is around that thing there, that little divot?

MR. GALLAGHER: I can't tell you exactly

what this point is. This point here would be one of those triangles. And then if that was the 711 one, then we would say this is the circle right here.

MEMBER BANERJEE: So this 18 inch thing would take all this area around it, right, more or less?

MR. GALLAGHER: Well, this is 2 inches, I guess, you know, it would be something in this neighborhood. But again, I don't -- I can't tell you if that's the 711 value.

MEMBER BANERJEE: Okay.

MR. GALLAGHER: Just because of the picture orientation.

MEMBER BANERJEE: Another 715 there?

MR. GALLAGHER: This could be any one of those points --

MEMBER BANERJEE: Okay.

MR. GALLAGHER: -- basically. But I just wanted to show you, because this would show you when you go in there, it's not like a pattern like you say, oh, here is a, you know, circle or here is an oval we should draw around. What we did was we -- like when we went into this bay the first time, we went in there and looked for what we thought were thin locations and then interrogated those and used them to determine whether the grid readings were appropriate and then continued those with -- as monitoring points.

MEMBER BANERJEE: Okay.

MR. GALLAGHER: Okay?

MEMBER BANERJEE: Okay. All right. So a picture is worth 1,000 words. Go ahead.

MR. MANOLY: The last slide. Yeah, basically our -- I'm sorry. The last slide basically summarizes our assessment and conclusions. That the analysis demonstrates that the -- all components of the drywell show adequate margin against instability under the refueling loading and post-accident condition.

The second conclusion that based on the evaluation performed for the baseline and the sensitivity, S1 and S2, the stresses in the cylindrical shell, stiffeners/gussets and star-truss stiffeners are less than the allowable ASME Code limits.

The third one is that for the refueling load case, the margin again is buckling in the lowest -- is the lowest in the cylindrical shell region, an area that has experienced little corrosion.

Overall, the Oyster Creek 3-D finite element analysis was performed utilizing good engineering practices and judgment and applied conservatively biased realistic assumptions.

An evaluation in all cases, baseline and sensitivity, confirm the Oyster Creek drywell shell complies with the ASME Code limits and provide reasonable and realistic quantification of the available safety margin of the drywell shell for the postulated loading conditions.

That's the end of our conclusions.

MR. WILKOWSKI: I think there is another conservative aspect here and one was on the flooding condition, because what they really do in their load combinations is they have the full flooding water level and then they apply an SSE event on top of that. You really have two really low probability events occurring at the same time. I could almost understand doing the flooding and then saying well, maybe I had a seismic event that caused the flooding, but it's going to take a long time for the flooding to occur.

Okay. And then maybe you have an aftershock at a later time and you would stick in an OBE, but not a full SSE. But it seems like a very severe post-accident type of loading condition.

MR. MANOLY: You basically comply with the loading combinations and the SAR, basically.

MEMBER ARMIJO: I never quite understood why you picked the 1.67 as opposed to the 1.34. Is that just arbitrary or was there a --

MR. MANOLY: No, I think they were complying with the commitment in the SAR.

CHAIR SHACK: Any additional questions from the Committee?

MEMBER BANERJEE: Did anybody sort of do a spot check of their analysis or the details of the analysis for a case?

MR. MANOLY: We did --

MEMBER BANERJEE: Or did audit?

MR. MANOLY: Yeah, we did two audits. One in the -- I think it was the January time -- was it January or February time frame when we -- after we received analysis. We actually sent 21 questions that they responded to during the audit, those areas that we had some questions on.

MEMBER BANERJEE: Somebody went to the way it was set up, the input?

MR. MANOLY: Yeah, I mean, it was basically Hans and I and I think Allen also joined us. We looked at -- sampled, you know, the analysis. We talked to the people who did the work. And we were satisfied based on that. And we also did the audit last friday, Allen and I, on the change on the assumptions that were made, the simplifying assumptions that Dr. Miller suggested to them. And we were also comfortable with what was done.

MS. LUND: And they went to look at some of the calculations themselves, because they had proprietary design details in them, so they could not be submitted, you know, for public release the same way as the summary report was.

MEMBER BANERJEE: Okay.

MEMBER MAYNARD: What becomes of this analysis as far as for future use? The -- from what has been stated, the 1992 GE analysis is still the --

MEMBER SIEBER: On the record.

MEMBER MAYNARD: -- licensing basis analysis of record done, this is to kind of help better characterize margins and stuff, but as far as what is its applicability from a regulatory standpoint, if any?

MS. LUND: Well, right now, their acceptance criteria is based also on the GE analysis. So when, you know, they do their outages and they do the UT measurements that's in order for them to make this their current licensing basis, they would have to submit that and also, you know, whatever their acceptance criteria would be for their outages.

You know, the intent of this was to really look at the margins and what, you know, inspection intervals to understand better what was available. Up to now, they have not submitted it for -- you know, to substitute for their current licensing basis and their current licensing basis remains valid. It's conservative, I think, that this is the conclusion the staff has reached on this, so that satisfies the requirement to have that.

MR. MANOLY: I may just add that I don't-- I mean, we may debate this, but I don't -- I'm not sure that they have to submit it if they want to incorporate that in the licensing basis analysis. Because it's basically more detailed analysis with increased margins. So they could choose, if they like to consider, that by 50.59.

MEMBER MAYNARD: Don't get me wrong, I'm glad they did this. I think it just sounds to me like if they wanted to be able to actually use this for much more, there would be some additional submittals and reviews that would have to be done if they wanted to change their licensing basis to this analysis.

MS. LUND: Right. Because the factor of safety that they found from doing this are, you know, higher than what they found for the, you know, GE analysis. So you know, feasibly, they could do that if they would like.

MEMBER SIEBER: It's confirmatory.

MS. LUND: Right, exactly.

MEMBER SIEBER: It's confirmatory in nature and consistent with the analysis of record.

MS. LUND: And if they have an analysis that is more conservative as part of the record and they want to keep the more conservative one, you know, as their current licensing basis, then, you know, that's appropriate.

CHAIR SHACK: Any further questions? Okay. Mr. Webster, are you going to be the man up?

MR. WEBSTER: Let me just do a little intro while we're getting up the slides. Um, I'm Richard Webster. I'm from the Eastern Environmental Law Center. I represented the citizens groups on the relicensing challenge in this case.

And one of the clients was Mr. Gunter here who is from Beyond Nuclear, formerly of Nuclear Information Resource Service. And he was the Nuclear Information Resource Service client representative on that challenge. But we're not here today to talk about that challenge. We're here today to talk about the actual technical details of the analysis, rather than all the intricate legalities which need not concern you too much, you lucky people.

So I'm going to really concentrate on two things here. They are basically not all the -- how you get from the inputs to the outputs, which is what we have seen a lot of concentration on so far.

MEMBER MAYNARD: I'm sorry, are you having trouble getting the slides up?

UNIDENTIFIED SPEAKER: Yes, apparently.

MR. WEBSTER: They are on their way up.

MEMBER MAYNARD: All right. Good. All right.

MEMBER BANERJEE: Do you have copies of these?

MR. WEBSTER: I don't. I'll submit a hard copy afterwards, if that's okay?

MEMBER BANERJEE: Or you can send it electronically.

MR. WEBSTER: Actually, I already attempted to do that, but I got on -- I had a few problems with file size.

CHAIR SHACK: It depends on whether your email can take a 16 megabyte --

MR. WEBSTER: Right. Those of you with 15 megabyte limits didn't get it and those of you with 25 megabyte limits did get it. So that's the way it works. I'm not quite sure how you are supposed to submit an 18 megabyte file, but I'll figure that out after this presentation.

CHAIR SHACK: Put up an FTP site.

MR. WEBSTER: I guess that's the way to do it. So I want to concentrate today on really the front end and the back end. The outputs and the inputs. And really, if we can move to the first substantive slide, I think there are two fundamental problems here.

On the output side, really this analysis doesn't provide news we can use. There are problems with the way the current acceptance criteria are being employed. But this analysis doesn't allow us to solve those problems and actually find what the thickness margin, the limiting thickness margin is. And it doesn't allow us to actually have revised acceptance criteria that we can really use.

On the input side, we actually already had a hearing before the ASLB on this very subject. The Commission remanded the appeal back to the ASLB for some -- for a hearing and then a decision or a recommendation about inputs. And the ASLB came up with conclusions that are actually at sharp variance with the conclusions of the licensee and the staff and, of course, the licensee and the staff had full opportunity to present their opinions at the ASLB, as did we, and in the end the ASLB came out requiring some changes.

Basically, there are methodological flaws in their inputs. They thought that the estimated thicknesses were too thick. They thought the analysis was not realistic enough. We've heard a lot about realism. But actually, this analysis is not very realistic at all.

They thought it was not enough account of uncertainty in terms of the sensitivity analysis. And they didn't think that the applicant had an adequately justified enhanced capacity reduction factor.

So moving to the next slide. One of the problems here is that we have never been able to identify -- we have never been able to define the limiting margin. And if we move it all the way back to the first hearings that we had or the first meetings that we had, the theory was if we could find the limiting margin, we could define some kind of corrosion rate and then we could come up with an inspection frequency. And that was to try to provide a basis for an aging management plan.

The problem is we have never actually been able to do the first step there, which is define the limiting margin. The reason we can't do that is because Exelon has said that it cannot use its existing measurements to calculate the margin of the local acceptance criteria that it already has.

Also, I think there is a lot of misinformation about these internal, these external measurements. The internal measurements are taken in the very top of the sandbed region. The reason they are taken at the very top is because there's actually concrete on -- in two-thirds of the sandbed region, so you cannot access most of the sandbed region from the inside.

It turns out the way the corrosion works, because the corrosion really occurred below the sand and the sand was placed at strange levels. In fact, in four bays, the interior measurements are not in the corroded areas at all. So the interior measurements in four bays is just not useful to characterize the corroded areas, because they are not in the corroded areas.

And the other problem with the internal measurements, of course, there is 49 measurements in each grid, but the grids are very small. The grids are a quarter of a square foot. Each bay is 73 square feet. So one grid is a very, very limited spatial coverage. And so, therefore, in terms of the mean acceptance criteria, you really don't have data to compare in four bays or at least you don't have data that the applicant has been prepared to compare in four bays. There is a lot of debate about the external measurements and bays, which I'll get to later.

So fundamentally, if we got news we could use, we would reassess the acceptance criteria and we would actually define the margin, we would quantify the margin in terms of thickness, because thickness is what they measure in each outage. Well, not each outage, every other outage.

So the ASLB said that what we need to do is to provide an estimate of the amounts of margin that exists and to confirm that the analysis is, in fact, a conservative best estimate analysis. And I think somebody called the ACRS the -- which you guys may be familiar with, you also asked it to better quantify the margin and include sensitivity analyses that determine the effect of uncertainties regarding the extent of the thin areas.

As we have seen, the extent of the thin areas, is what we recognized all along, was extremely uncertain. And really we're back to full circle here. We are debating the extent of these scenarios. The idea was originally that we use sensitivity to say whether the uncertainty in the size, not just the thickness, but the uncertainty in the actual size really would affect the margin. And if it would, then I think the theory was maybe we need to define those areas some more and better.

Now, could this analysis have been used to give us a thickness margin? And the answer is yes. Actually, Exelon told its consultant to do that very thing on February 7, 2007. It said, basically, do a base case analysis and then just step the thicknesses down until you hit the safety factors or the required safety factors and that way you would actually derive a margin in terms of thickness.

Well, less than a month later Exelon changed its mind and said no, no, don't do that. And once more, don't use the external measurements to characterize the shell, which is what Sandia did, and it's what Exelon initially proposed to do, don't do that. Use the internal measurements. And then as we have seen, the sensitivity analyses that were done were extremely limited.

So I just want to space through the recommendations. There is a full opinion of the -- from the ASLB which I suggest if you haven't read it already, it's a very good thing to read, because again it's the output of a day's worth of hearings -- of oral argument, I should say coupled with some expert affidavits all about the same issues really, which is whether this analysis really is a conservative analysis or conservative best case analysis. And the board concluded that this analysis was not such an analysis and only with five recommendations would it become such an analysis.

Now, in their wisdom, the NRC staff decided not to implement those recommendations of the board. Exelon decided not to implement the recommendations of the board, but we strongly suggest to you that the ACRS should think carefully about implementing the recommendations of the board.

The first recommendation was that really this averaging process doesn't really work. You've got these big smooth bays, but in reality what you have got is a real surface roughness. And so there is no realism there in the way that the bays are being modeled. And the -- you know, as we have heard, areas of the order of 17 inches make a difference to the buckling analysis.

So the Licensing Board said well, basically, you should go back and start -- define the thicknesses along those kind of scales instead of just having these blanket averages. And then the Licensing Board concluded really that the analysis -- oh, I'm rolling all around here.

So for the first one, they basically, I'll show you in a minute, really talked about the need to look more carefully at the way these averages are developed. For the second recommendation, they really talked about the need to split up the bays into these 17 inch areas, characterize them more carefully.

Well, let's move ahead. Here we go. Now, this is actually two different Exelon documents. On the left is the model that was done and on the right is the average of the external measurements in various bays. I direct your attention to Bay 13. The average of the external measurements in Bay 13 is .786 inches. But Bay 13 was modeled at a thickness of .907 inches. So that's 111 mils, that's 14 percent thicker than the average of the external measurements.

Similarly, Bay 15, the average of the external measurement is .788 inches. Bay 15 was modeled in the bottom part. It was modeled at .935 inches. There's 140 mils difference, that's 14 -- that's actually 18 percent difference. 18 percent thicker.

Um, so the other interesting thing about this is actually in many of these bays, the grids are not representative. In four of these bays, there is no representative data. The way Exelon did it, for instance, in Bay 1 instead of saying well, we have -- we don't have any representative grid data in Bay 1 from the inside, so let's look at the external base and they said no, what we will do with Bay 1 is we will just pretend it's the same as Bay 19.

We talked about photos. We need to look at these photos and I totally agree with that. This is Bay 13. And really what you see is there is a lot of misinformation about what this corrosion looks like. It has really occurred in the sand -- the water interface. It really occurred throughout the place where the sand was.

And so what you see is that above where the sand was, which is the top of the picture, you see basically a non-corroded area. Once the sand was there, you see generalized corrosion. And the generalized corrosion is throughout top to bottom and it's in every bay. This idea that half the bays are uncorroded is completely wrong. The corrosion is in every bay and it's top to bottom.

Now, looking at the measurements then, these are looking at the external measurements. The internal measurements are way up off the top of this grid. Now, the things that I sort of notice about these external measurements is that actually they didn't interrogate the entire sandbed area. This is actually to scale. We spent quite a bit of time taking Exelon's measurements and putting them on a grid to scale.

And to scale, this grid goes from -30 to 48. The actual width of the sandbed is to go from -84 to +84. So they are already interrogated from the outside a very small area. Which is one of the reasons why you tend to underestimate the severely corroded areas, because you just haven't measured a ton of them.

If we look on the middle to the left, you see the thinnest point that they measured this point, 6.02, is actually that red region on the very edge of the area characterized.

CHAIR SHACK: Just out of curiosity, how are your counter plats generated?

MR. WEBSTER: Okay. They are just generated from a standard countering interpolation program. The -- what is overlaid here, there is a contour -- the measurements themselves are actually given a data label, you know, point number whatever and then the next number is the mils that are measured in that point.

Then the contours were generated with the standard contouring program, which interpolates between these points. And then these black areas are actually the areas that Exelon assigned as thin areas for evaluation. And again, I mean, you can draw these, as you have noticed really, thin areas almost wherever you want because, you know, the edges of these areas are not characterized at all.

I mean, you have no idea what is going on in these regions beyond the photo and the photo just tells you you have a rough surface and you really can't spot from the visual inspection from the outside where the thinnest regions are. The idea that these divots show you that there is over-grinding, I think he is wrong.

What the divots show you is that there is grinding, but it doesn't show you that the thinnest point on the divot is any thinner than it was in the first place. And I'll --

CHAIR SHACK: If you draw their circles on your plots --

MR. WEBSTER: Well, what you will see is, for instance, Bay 13 -- basically, the circles are much smaller than what you expect.

CHAIR SHACK: But when I put them -- I mean, I have done it.

MR. WEBSTER: Yeah. Go ahead.

CHAIR SHACK: And it seems to cover fairly generously the area that is thin.

MR. WEBSTER: Well, let's go to -- for instance, Bay 13, I think the spot -- the circle -- can we get that back up? There we go. Right. So Bay 13, I think that the spot covers the one that is on the right here, that's something around -24 or -20. But there's actually another thin area up on the other side here which actually got lost out of the calculations because this is a thin area they measured back in the first round in '92, but they weren't able to repeat these measurements for one reason or another in 2006. So this area just got dropped off of the calculations completely.

CHAIR SHACK: The thinned area more than covers the thinned area in your plot by a fairly healthy margin.

MR. WEBSTER: On Bay 13?

CHAIR SHACK: On Bay 13. Well, I've done them on all the bays, but --

MR. WEBSTER: Okay.

CHAIR SHACK: -- some bays are better than others.

MR. WEBSTER: Okay. Okay. Well, I hadn't done that analysis, so I think you for that.

MEMBER BANERJEE: Yeah, I also looked at that recently.

MR. WEBSTER: Um-hum.

MEMBER BANERJEE: I mean, the circles they are drawing are enormous compared to these areas.

MR. WEBSTER: Um-hum.

MEMBER BANERJEE: So I think that more than conservative, which is why I sort of gave that argument --

MR. WEBSTER: But at any rate --

MEMBER BANERJEE: -- more --

MR. WEBSTER: -- you should draw the circles on your plot.

MEMBER BANERJEE: Okay.

MR. WEBSTER: I mean, I think one of the problems is that we don't have enough -- like I said, these plots are really not covering -- I mean, these measurements are really not covering the entire bay. That's really the biggest problem. So we're really interrogating a very small portion of the bay. We're interrogating the middle of the bay.

Now, we think the reason that happens is because they are accessed when they actually crawl into this bay, which remember is 15 inches wide, it's very small. Now, when they crawl in there, they start in the middle, so the actual tendency of somebody taking measurements when they're just told well, just take a few points and get out of there is to just take the points needed when they get there.

And so I think, for instance, if we look at the next slide on Bay 1, what we see again on Bay 1 the thinnest area is off to the edge. And on Bay 1 we see this groove on the console plotting which is what is being observed as the bathtub ring. But that again wasn't reflected fully in the --

CHAIR SHACK: The circle again --

MR. WEBSTER: Yeah, the circle covers it, okay. The other point I want to make is that the -- this idea that it didn't go top to bottom, if you look at the bottom point down there, the .16, which is at about 40 minus 50, that's a thin point there, that's

795. So you got top to bottom corrosion. You've probably got completely left to right corrosion, because you see adjacent bays are quite similar.

They are not similarly corroded. Adjacent bays have somewhat correlated levels of corrosion. So you probably got corrosion that goes much, much broader than these particular plots, but we just have never taken any measurements to investigate it. To cover the 1,000 points, the 1,000 points were in this lower part of the sandbed region, because you couldn't get to it at the time the 1,000 points were taken. The 1,000 points were actually taken, I think they were taken, all over the shell with some circumferential sweep in the sandbed region at the high level.

The problem is the high level is above the most corroded area. So the 1,000 points are neither here nor there. They don't really tell you very much at all. And the big problem is we really have never taken enough points in this corroded area to properly characterize it.

Now, in terms of bias. The reason that they claim that -- the applicant claims or the licensee claims that it can't use these external measurements to characterize the average in bays where the internal measurements are -- well, in all of the bays really, but especially in the bays where there are no representative internal measurements is they are claiming there is a bias.

And now we looked at this --

CHAIR SHACK: You wouldn't have any trouble using the internal numbers above 11 feet, would you?

MR. WEBSTER: No, no, right. Above 11 -- well, it depends on the shape of the -- I mean, if we go back to that picture, if you remember, you know, that's not a horizontal line. Where the corrosion is is not a horizontal line. And so what you actually see at 11 feet is that parts of it are uncorroded and parts of it are severely corroded.

And so you have to be careful when you are using these internal measurements to make sure that they actually are representative of what is going on rather than just the fact that part of the bay is no corrosion and another part of the bay there is quite a bit of corrosion.

And again, it really goes to the idea that you probably can't average or you certainly can't average the whole bay. It's really just too much averaging to be realistic. What you need to do is assign which area is above 11 feet within the bay are corroded?

I mean, we have no problem with using the -- we have no problem using all the -- we have very few measurements already, so it seems like a bad idea to not use some of them. I mean, that's the fundamental principle to work on is let's use all the measurements that we can and then if the analysis comes out to be indeterminant, then you -- maybe you need to take some more measurements.

CHAIR SHACK: Fundamentally though, I mean, you know, the question is how much credit to give the licensee for having chosen points to make measurements that he thinks --

MR. WEBSTER: Right.

CHAIR SHACK: -- are the worst.

MR. WEBSTER: Well, right.

CHAIR SHACK: And that is his visual inspection.

MR. WEBSTER: Right.

CHAIR SHACK: And you know, so arguing that he is averaging over a whole bay on the basis of these small ones is perhaps a bit unfair in the sense that he has tried to bias his average.

MR. WEBSTER: Well, okay. That's not

exactly what he argued actually. We thought -- we looked at that in quite a bit of detail actually after the hearing when we fully understood the argument. And what we found is looking at this argument on bias, actually, only two -- only 28 of the 104 points were ground at all. There is one document that says there is bias between .03 to .1 inches on the -- on some of those ground points. So the bias from grinding is the best, quite small on a very limited number of points.

If you compare the internal to the external data, whether -- where there is representative internal data, in other words, where the corrosion goes up past the 11 feet mark. You see that in 3 out of 6 bays actually you get pretty close agreement, which tends to indicate that there is no real methodological bias because you're one way or the other.

And if you look at the selection bias, actually, the surface roughness is of the order of .1 inches. So the selection bias couldn't exceed more than .05 inches. And actually when we looked for selection bias, statistically in the measurements, we didn't find any. So although they were trying to spot the thin points, the problems is they are in a very dark small area with a lamp or something. Actually, you are faced with a very irregular surface. So it's an extremely difficult task to actually spot the thinnest areas given that situation.

So the bias issue really there is no -- there has been no clear evidence of bias. There has been some anecdotal discussion that maybe there is some, but when you actually look at the data, really analyze it, it doesn't appear to be there.

And the final thing the ASLB wanted was more sensitivity. They basically acknowledged that the uncertainties are much larger than the applicant's sensitivity analysis was taking account of. So they suggested that the general area -- the amount of reduction should be increased to .075 inches. And they suggested instead of just thinning one bay, Bay 1, or instead of just thinning Bay 19, they should actually thin Bay 19 and Bay 1 at the same time, because that would then take more account of these uncertainties with the theory that, you know, if it comes up, okay, when you take account of these uncertainties, then maybe you don't have to make it more certain.

And finally the ASLB commented that it wanted to check on the capacity reduction factor. They actually suggested that the studies that Sandia weren't given originally, and therefore said because we weren't given these studies, we were unable to justify the use of this capacity reduction factor. They suggested that the best approach was to give those studies to Sandia and let them look at the studies and make a -- take a view on the applicability of this capacity reduction factor issue.

I just want to finish off with a little word about the way the current acceptance criteria works. Because one of the problems we have got here is the current acceptance criteria have not been set properly. At the moment, the current acceptance criteria actually allowed the shell, according to the GE analysis, to go below the safety factor of 2.

That's because when you put on the thin area, the uniform thin area down to .736 and then you also allow these locally thin areas, actually what that gives you is a shell safety factor depending on the depth of the cutout area of 1.93 and 1.81.

So the problem is you could accept these. And in theory with the current licensing basis, because the staff claimed -- what the staff did in the hearing was the staff said well, this is right this acceptance criteria because the safety factor 2 is not part of the current licensing basis.

Staff's argument was that the safety factor 2 was just another factor, it wasn't part of the licensing basis. The board actually and the Commission subsequently rejected that argument and said yes, the safety factor 2 is part of the licensing basis, but only one judge figured out or recognized or put in the opinion at least that once you take that step and have the safety factor 2 be part of the licensing basis, you then have to change the acceptance criteria, because the acceptance criteria allow the safety factor to go below the licensing basis.

This is the cutout that Exelon is using for its local area acceptance. It's 3 x 3, 3 foot by 3 foot and it slopes down to 1 foot by 1 foot in the middle. The problem is they can't calculate the margin above this criteria. And the reason they can't do that, if we look at the next slide, is because, you know, you have to draw areas. So you might think, for instance, with this criterion that you would say well, I don't want any contiguous thin area that is below .736 to be larger than 9 square feet, 3 by 3.

But actually, you already have areas that are contiguously thin, bigger than 3 by 3. So there is a lot of complicated drawing of numbers and so forth, drawing of lines which, you know, you can draw these lines however you want. Basically, the bottom line is there is no objective way of passing or failing these criteria.

Indeed, we believe that they already fail these criteria, which is not to say that that necessarily proves that there is a problem with the actual shell itself. All that proves is that there is a problem with the criteria.

If we look at -- this is -- again, going back to Bay 1, the problem with this is that the, you know, cutout area just isn't the same shape as the actual finished areas. And so it's not very clear how you can apply when you have a long thin band of corrosion, the "bathtub ring" how do you apply that square cutout area, which is analytically just -- nobody knows how to do it.

And so that acceptance criteria is not proving remotely useful. And so we need an acceptance criteria that would actually tell Exelon when, if they find corrosion, which they did in this outage. They didn't find much corrosion, but they found some corrosion. You know, if corrosion occurs in the future, how will they know when too much has happened?

At the moment, they really have no way of telling that. They're basically banking on well, we'll know when we see it.

And finally, I just wanted to finish off, this is a quote actually back from the Brookhaven, yeah, I swapped the order around and pulled this one up from the back, and what they really said was look, we -- this -- when they accepted the GE analysis back in '92, they said that we want some extra measurements. The measurements -- these extra measurements should cover not only areas previously inspected, but also accessible areas which have never been tested, so as to confirm that the thicknesses of the corroded areas are as projected and that the corroded areas are localized.

Both of these assumptions are the basis of the reanalysis and the staff acceptance of the reanalysis results. So that was the condition of the acceptance of the GE report was that they show that these corroded areas are highly localized.

And I think what the results actually showed and the photos and everything actually shows that these corroded areas are not highly localized. They are quite generalized. And so you have quite generalized thin areas. And so you have to go -- that means you have to go beyond the GE analysis and you have to have another analysis of record.

And the current analysis, obviously, isn't up to providing you with what I call news you can use, i.e., a means of deciding whether future measurements are acceptable or not or, indeed, whether current measurements are acceptable or not.

But it is our belief that that would be the best use of this analysis. It would actually close the loop on all of this and finally put some kind of analytical rigor back into this process. Because we really have a process. We have an old analysis which we know is -- first of all, doesn't meet the criteria. The criteria on which this has all been accepted have now been broken.

And second of all, we know that we have much better capability of doing good analysis. So it really doesn't make sense to cling to this old analysis, because people don't want to actually go through the process of amending the license.

CHAIR SHACK: I hope your corrosion occurs under a support beam. Actually, it was a lot easier with the old access symmetric analysis. Now, the worst corroded bay, not the limiting bay, but the worst bay is the one --

MR. WEBSTER: Well, actually, you know,

the worst -- for the loading, for the post-accident the most corroded bay is Bay 19. The limiting bay is Bay 19. So it is -- and that's the most corroded bay that Exelon has measured. I'm sorry, that it has modeled. But the problem is Bay 1 is actually more -- Bay 1 is more corroded than Bay 19 by every measure.

But they just didn't account for those measurements fully in terms of the average of Bay 1 in the analysis. So you would find if you did these corrections of generalized areas that we believe are necessary to make it realistic, you would probably find that the margin would drop. I mean, the thickness over-estimate is of the order of maybe between 5 and 10 percent.

The margin overall in terms of, you know, margin of safety factor, you're looking at a margin of about 20 percent. So you're looking at a 5 or 10 percent reduction in the thickness, another 5 or 10 percent on the sensitivity and so, you know, we're not as comfortable, I guess, as the licensee and the staff are in terms of saying this analysis shows everything is complete fine. We believe that this analysis really shows and really a lot depends on where the CRF discussion comes out in the end. But even with the enhanced CRF, we believe this analysis shows that in the end you're kind of close to the edge here and you need to be careful.

And so, therefore, you need to be clear what measurements you're going to accept and what measurements you're not going to accept. And at the moment, that's just completely unclear. So we hope that you will delve into the rather opaque subject of what measurements were taken when, by whom and what they show.

And I think what they show is that really we need to be very careful, because the characterization is poor and at the moment, Exelon is assuming things that it has not shown. And it's assuming that the external measurements are biased then, when actually there is no showing of that at all.

So that's all I have got for you. If you have questions?

CHAIR SHACK: Your table back there where you were doing those averages with the external, let me just -- you are proposing those would be general thicknesses of the whole bed for the bay?

MR. WEBSTER: No. What we are saying is that this is just -- this is Slide 7. Is that the one you want?

CHAIR SHACK: No, that one may do, but it wasn't the one you were speaking of at the time.

MR. WEBSTER: Oh, I know the one, right. This one.

CHAIR SHACK: Yeah, yeah.

MR. WEBSTER: No, I mean, what we are proposing is that actually they should -- we are really -- basically, the Licensing Board that instead of having these big averaged areas, you need to break it up into areas out around the buckling, the critical buckling length scale. I mean, you don't need to go down the mesh cycles, that's very small. But we believe that you need to break it up, so that you actually characterize the sandbed on the scale that will actually affect buckling.

MEMBER BANERJEE: I just have a question. If you look at Bay 1, they have a large diameter circle of 696.

MR. WEBSTER: Um-hum.

MEMBER BANERJEE: Right. Which you are saying -- so I'm not following your argument.

MR. WEBSTER: Okay.

MEMBER BANERJEE: So that they should consider Bay 1? They consider Bay 1, right?

MR. WEBSTER: Well, for the average of Bay

1, we're saying that they overestimated the average thickness of Bay 1.

MEMBER BANERJEE: You think 826 or whatever is an overestimate?

MR. WEBSTER: Yes. I mean, that's not the worst overestimate of the average, but the -- 826 is actually an underestimate of the top part of Bay 1 and it's an overestimate of the bottom part of Bay 1. Actually if we go back to -- if I show you Bay 1 --

MEMBER BANERJEE: There's a large 51 inch circle with 696 there, right?

CHAIR SHACK: Well, at the moment, he is focusing on the averages, rather than the thinned area.

MR. WEBSTER: Right. I mean, one thing about Bay 1, I mean, even if the average -- to get the average in Bay 1, actually, what really happened in Bay 1 was they went out and saw this grooved area when they first walked into the sandbed region after the sand had been taken out. And then they actually measured some points and they came in so thin that they couldn't believe that the meter was working.

So they did a round of points and then they went up to the top. And you see these points on the top there, there is .15, which is up at somewhere around -4, -8 and there is .14, which is up at something like 34 minus 2.

Now, they took those to check that the meter was working, because those were in the actual uncorroded area. And they did, they came out right. They came out just around nominal things. But at the moment, the applicant keeps including these in his averages, which we don't think makes any sense.

What you really need to do with Bay 1, really with all the bays, is split them up into -- instead of just having these two zones, the upper and the lower, you actually need to split it up more than that. But if you just split it up into upper and lower, if you cut those two measurements out, what you would find is the average of the external measurements for Bay 1, I've got it on the slide there actually, is .768 inches.

They are modeling it at .82, I think. And actually, the real thing, the best estimate of the thickness that we have got -- in fact, the only data that we have got, because they don't have an internal data in Bay 1 that is representative, so the only thing we have got in Bay 1 is telling us that the thickness of the lower part on average should be something around .76, .77.

So my primary argument is that the average thicknesses are overestimated and are anyway cover far too big an area.

My second argument is that the assigned -- these thin areas is kind of arbitrary, because we don't have any way of bounding the edges. Yes, they draw them around the points that they have got, but what we don't know is what is in the regions where they haven't measured them.

I mean, from the photos, the regions they haven't measured look much the same as the regions they have measured.

CHAIR SHACK: Okay. Any more questions?

MEMBER ABDEL-KHALIK: You raised some questions about the margin.

MR. WEBSTER: Um-hum.

MEMBER ABDEL-KHALIK: Wouldn't these two sensitivity studies that were run suggest that as far as an area as big as an entire bay, that you have more than 100 mils of margin?

MR. WEBSTER: Yes.

MEMBER ABDEL-KHALIK: Okay. Wouldn't the second sensitivity also suggest that --

MR. WEBSTER: Well, no, actually the entire bay was .05.

MEMBER ABDEL-KHALIK: Right, right. So an area the entire -- the size of an entire bay, you have at least 50 mils of margin?

MR. WEBSTER: Yeah, right, it would.

MEMBER ABDEL-KHALIK: And an area that is a localized area that is 51 inches in diameter, you would have at least 100 mils of margin?

MR. WEBSTER: Well, although what we are saying is that -- and actually I don't know. I mean, I think it's not clear how -- if you divided up these areas more finely into -- and made a more realistic analysis, it's not clear whether the base case would give you more margin or less margin.

Our supposition is that the margin would decline because of the overestimates of the averages. And so because -- you know, what it suggests is that a thinning of one bay by .05 inches makes a relatively small difference to the margin. I think about 8 percent. But my point is we don't know where we started. We don't know that the base case -- we believe that the base case already overestimates both the thickness and realistic in terms of -- because it is too smooth.

MEMBER ABDEL-KHALIK: Um --

MR. WEBSTER: And so you can't, therefore, tell really. The sensitivity analysis gives you a feel for if you change something, how much you change it by, but you need to know how close you are. You need to know -- you have to quantify how close you are to the edge before you can really conclude anything from how much you would move.

MEMBER BANERJEE: So you're suggesting that 50 mils reduction in Case 2 of the sensitivity analysis had a relatively small effect on the margin?

MR. WEBSTER: Yeah.

MEMBER BANERJEE: A very small effect?

MR. WEBSTER: Yeah.

MEMBER BANERJEE: You're saying that for some reason that that's not an important result?

MR. WEBSTER: No. Well, I guess, what I'm saying is that I think it's important that we know more adequately what the actual margin, in terms of thickness, is. Because we really don't know at the moment whether -- you know, if we find localized corrosion, say .01 inches or something, we don't know in a certain area.

The corrosion that was found in the last outage, for instance, was a very small amount of corrosion. I think we can tell from this analysis it's going to make no difference whatsoever to the actual buckling of the shell.

But let's assume that we get a little more corrosion and it happens to be in an area that's already quite thin. At the moment, we really don't have a good way of evaluating that. And I think, you know, we would be much more comfortable if the analysis actually made an attempt to be what it was supposed to be really, which is a realistic conservative analysis. Because then you would know in terms of thickness how much margin you have, that would enable you then to make some estimates, for instance, of inspection frequency. And to make sure that your inspection frequency is adequate.

MEMBER ABDEL-KHALIK: Is there anything in the physics that suggests that we are anywhere near a cliff? You know, that instead of having a sensitivity study with 50 mils of thinning, you would do a study with 75 mils of thinning, that we are near a cliff?

MR. WEBSTER: Well --

MEMBER ABDEL-KHALIK: Have you seen the physics that suggest that?

MR. WEBSTER: Not as far as I know, no.

MEMBER ABDEL-KHALIK: So what's the point if a change in the thickness of 50 mils caused a minor reduction in the safety factor?

MR. WEBSTER: Right. The point is not because actually you are thinking that change might happen. The point is it's because the uncertainty of the characterization. The sensitivity analysis isn't -- I would suggest to you the sensitivity analysis isn't really designed to set acceptance at the moment. It's designed to say well, actually because we haven't done a lot of measurements of this -- of each bay, we are at least 50 mils uncertain about what the average thickness is.

In fact, the Licensing Board having spent some time on this found we are more -- found we are 75 mils uncertain in two bays. And so it's not really about saying can we observe 50 mils of corrosion in the whole bay? It's really about saying well, we're already uncertain about what values to assign.

MEMBER ABDEL-KHALIK: Well, that's the basis to my question as to whether or not we are near a cliff from a physics standpoint.

MR. WEBSTER: Well, I don't think we are near. I mean, I don't -- I guess all I'm working from is the licensing basis, which is a safety factor of 2 or 1.67 and saying we are about -- seems about 20 percent above those. And you don't -- you know, you don't need normally a cliff to get pretty close to those if you start to make some of these changes.

MEMBER BANERJEE: But their number is like 1.98 after they have reduced the thickness by 50 mils for the case where the 1.67 is the --

MR. WEBSTER: That's right, yeah.

MEMBER BANERJEE: There are substantial -- and the base case is 2.01.

MR. WEBSTER: Yeah. I don't have a big -- a good feel for how changing the extent -- at the moment, they have changed the thickness of one bay. And I don't have a good feel for whether -- how much changing the thickness of the two bays together would really change the analysis, you know.

CHAIR SHACK: But you know, we have got bays that are ranging now from .663 to, you know, 1.074 and the safety factors don't change a whole lot.

MR. WEBSTER: Yeah.

CHAIR SHACK: You know, that just sort of is consistent with the sensitivity analysis that says that, you know --

MR. WEBSTER: Yeah.

CHAIR SHACK: -- at least in this kind of range of numbers, you know, maybe if we thinned the .663 one down and thinned that one down, but -- yeah.

MR. WEBSTER: Well, I mean, by the way,

the other point I wanted to make was that in terms of the stress analysis, I think there is a thought that, for instance, from Bay 1 if you had that very -- if you had that step-wise change where you have a thick uncorroded part and it steps down to quite a thin corroded part, that you could get through special concentration effects.

And again, you're not. The stress, as far as I can tell, and there hasn't been a lot of discussion of the stress analysis, but as far as I can tell you're not -- there is not masses of mileage in there either. Like about 20 percent or -- no, actually 10 percent on the stress in the worst cases.

So that -- actually, just to -- the Licensing Board decision about more realism in terms of the areas is actually, I think, primarily based upon the need to be careful about stress concentration, rather than the change in the buckling.

CHAIR SHACK: Further questions?

[No response.]

CHAIR SHACK: Thank you very much. My thanks to the licensee for a fairly exhaustive presentation today, and the staff for their presentation.

Do we have questions that need to be

addressed at the full committee meeting? Particular questions.

MEMBER ABDEL-KHALIK: I would like a more clear explanation of the boundary conditions with regard to these vent pipes.

MEMBER BONACA: Say that again.

MEMBER ABDEL-KHALIK: A just more clear explanation of the boundary conditions with regard to the vent pipes, particularly the statement that these were not loaded for the buckling analysis. I'd like to understand what that means.

MEMBER MAYNARD: Just to expand on that a little bit. Now personally, I'm not concerned about the buckling of the vent lines. It's more of how was this modeled and the loading applied, so that you evaluated the shell. What kind of effect did it have on the shell analysis there? If you didn't load it for buckling and have all the details for the vent pipe, that's fine. But what was done to assure that the analysis for the shell, that had the proper loadings applied to it?

MEMBER BANERJEE: I think my view is, for my purposes, I think you've explained how you selected the areas and so on. But a little more clarity for the full committee I'm sure would be welcomed, how this was done and justified.

CHAIR SHACK: Yes. I mean, we're at rocket science for the analysis and it's--you know--

MEMBER BANERJEE: Inputs.

CHAIR SHACK: The input, you know, does require judgment, and I think that, you know, the problem is that we're in fact combining a limited set of data with what you and the staff feel are kind of an overall feel, that, in fact, these data are really sufficient to characterize it, and I think that's hard to convey to a audience that isn't as familiar with the overall condition, and anything that you can sort of do to assure, increase the certainty that you've identified the right places to make the measurements. Perhaps a little bit more detail on just exactly how that was done would be helpful in convincing us that your samples are, if anything, a slightly biased sample, because as Mr. Webster--you know, you really are looking at a very small sample of this and arguing that that's characteristic.

And that's satisfactory if it's bias, conservatively. I think that's the sort of argument, perhaps, that has to be made. I'm a little more comfortable, actually, with the local areas, just because wherever I draw those circles, they look pretty big compared to all the data I've seen.

But, you know, we are looking at the thin regions for the average thickness. The most comforting thing is to look at the results and find out that everything works.

MEMBER BANERJEE: Well, the sensitivity analysis gives some assurance but--

CHAIR SHACK: Well, even, even the--you know, the overall analysis, just looking at the variation between the bays, even before the sensitivity analysis--you know, since we are looking at local buckling, you would think that would be a, sort of a local problem, bay by bay, and yet--

MEMBER MAYNARD: It kind a has a built-in sensitivity analysis by just comparing the bay to bay in the different realms there.

MEMBER BANERJEE: But anyway, somehow, the sensitivity analysis, and the way you characterize the measurements, work as a whole, in my view. In some sense, the fact that you can get a very comprehensive coverage of all these areas, and things like that, are compensated, issued to an entire sensitivity analysis, and show that it doesn't matter if I don't have this bounded so precisely, and all that sort of stuff. You know what I mean?

Sensitivity analysis, in some way, can compensate for having very detailed measurements and stuff, which characterize the areas very precisely.

So those two things have to work together in some way, and it must be made clear to the full committee, that the fact that you don't have complete coverage and detailed measurements everywhere, which were impractical, are compensated for because you have sensitivity analysis which indicates that it may not make that much of a difference because you're being conservative.

I would say that would be an area which, knowing the full committee, would be looking at.

MEMBER SIEBER: I guess I struggle a little bit with the input data like everybody else is. I would have felt more comfortable had the, instead of--if the input data had been taken on a grid basis, and the input data applied to the finite elements, based on that, you end up getting a better localized picture of what the thickness really is, than by taking data and averaging, and picking this and leaving that one out.

So I have to sort a reconcile, in my own mind, whether that process really gives you the true realistic case, and beyond which the sensitivity analysis tell you, really, how much margin you have if you're off a little bit.

And so the data that they have, though, is not systematic, it's intelligently selective. In other words, you find a few little places, you make more measurements around that, and then when you take those and average them with some other measurements, it's not clear to me that you get the most stressed area identified in the liner.

On the other hand, I do have some comfort in those real--the lower areas are relatively small and we know that if you take a drill and drill a 3-inch hole through it, it won't buckle anyway, and that's a zero thickness.

So I just would feel more comfortable if it had been a little more systematic and that we have taken the full range of the data. On the other hand, the modeling I think is very good, and we probably have more elements than we need because we have data smeared over multiple elements, and to define the geometry--I don't think we need that--but if you got the computer capacity, you might as well use it, and, you know, that's why I keep buying new computers all the time.

But other than that, I think that

everything else was pretty well done. We're not in competition with the Atomic Safety--

MEMBER BANERJEE: Certainly, the stress analysis seems very thorough, and--

MEMBER SIEBER: We're not in competition with the Atomic Safety and Licensing Board. They do their thing and we do ours.

MR. WILKOWSKI: One observation I made was looking at the mode shape graphs was since to see, and the one that had the buckling in the sandbag region actually had a circumferential length that looked like it buckled over about two bays.

So if you're going to do sensitivity studies, maybe you need to do it over that buckling length, and I think that would be helpful because that's where that buckling mode is coming into play.

MEMBER SIEBER: But the sensitivity studies they did were fairly severe, I thought--

MEMBER BANERJEE: Well, if you sensitize just a local area but the rest of it's being stiffened, because it's thicker off to the side, you may not see as much.

MEMBER SIEBER: Yes; yes.

MEMBER BANERJEE: Of course unstable eigenvalue is the idea, it has a wavelength--

MR. WILKOWSKI: Yes. It was going, you know, about two bays or so, but, you know, that'd be nice to see, and do that sensitivity study a little wider.

MR. GALLAGHER: I guess at the risk of asking a question, that I may not want the answer to, and I don't want to cut off any feedback, so if there's more feedback, I want to get that. I just want to make sure that we deliver what's needed for the full committee meeting, and so there's a lot of detail, requests here, which I understand and would have expected, you know, because of the interest in, a technical interest in analysis.

But I would like to bring us back to--our commitment was to quantify margin and we think we've done that.

So what of these detail things do you need, or should we bring back to the full committee so you can make your, whatever--I don't know what your final product is on this either, but--and again, I just want to make sure we deliver what's needed.

So, you know, if you need the information on this detail, we'll get it. If it's kind a more of a curiosity type thing, and, you know, you think you have enough, that we show we've met our commitment, then I guess I would just like to hear a little bit more about that, if that's possible.

CHAIR SHACK: That requires consensus. What you're getting are views of individual members and you will have to, you know, draw your own consensus from that. But he does not speak until the committee speaks. Otherwise--

MR. GALLAGHER: That's what I figured you'd say.

CHAIR SHACK: But you could hope.

MEMBER SIEBER: And beyond that, you know, you've done the work that you can do with the information that you have, and I don't think there's question about the technique or the methods, or even the data. You've got the data that you have and you have to deal with that. So other than making a presentation that honestly portrays what you've done and the conclusions you've reached, I'm not sure what else you would do.

MEMBER ABDEL-KHALIK: What would be helpful would be, really, a justification for the two sensitivity analyses that is anchored in the measured data, in a sense that you're saying, okay, I've done a sensitivity analysis where I reduce the thickness of one whole bay by 50 mils and I've done another sensitivity analysis where I've reduced the thickness of the thinned area by a 100 mils. Presumably, that should give us, you know, a feel for how the actual variations in thickness, both locally and on a larger scale, would have a relatively minor impact on the calculated safety factors.

So if you can sort of anchor the basis for the sensitivity analyses, the two calculations that you've done, to the measurement data, that would be very helpful in saying, yes, these sensitivity analyses are meaningful, they bound the kind of questions that a sort of inexperienced engineer would have asked based on the data.

MEMBER MAYNARD: My personal feelings are I don't think there's a need for any additional analysis. I think there's a need for some better explanations on some things. I think we need to keep in mind that this is not being proposed as a new licensing basis, or as something to be used for decisions.

So I think we need to keep it in perspective as to what we're reviewing too, but to me, a better explanation on a couple of things that would be beneficial.

MEMBER BONACA: I second his comments.

MEMBER SIEBER: Did that help you?

MR. GALLAGHER: Most definitely.

MEMBER BANERJEE: Have also backup slides in case you're asked.

CHAIR SHACK: All right. More?

MEMBER BANERJEE: I've already made my comments. I'm not going to make any more.

CHAIR SHACK: Well, I think we can adjourn for the day, then.

[Whereupon, at 4:46 p.m., the meeting was adjourned.]

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Oyster Creek
3D Drywell Analysis

ACRS Full Committee
October 08, 2009

Agenda/Presenters

- ✓ Summary of 3D Drywell Analysis
- ✓ Resolution of Questions from September 23, 2009 Subcommittee Meeting
- ✓ Presenters:
  - Mike Gallagher
  - John O’Rourke
  - Stan Tang
  - Dr. Clarence Miller

Background

- ✓ Exelon made a commitment to perform 3D Drywell Analysis at the February 01, 2007 ACRS Meeting
- ✓ The ACRS described Exelon's commitment in its February 08, 2007 letter to Chairman Klein as follows:
  - "The applicant has committed to perform a 3D finite-element analysis of the OCGS drywell to determine the margin of the shell in the as-found condition using modern methods. This analysis will provide a more accurate quantification of the margin above the Code required minimum for buckling. …. The analysis should include sensitivity studies to determine the degree to which uncertainties in the size of thinned areas affect the Code margins"
- ✓ Exelon formalized this commitment in a letter dated February 15, 2007
- ✓ The analyses were submitted to the NRC on January 22, 2009.

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Overall Results (Sandbed Region)

Load Combination Case	Required Safety Factor	Base Case Safety Factor (Limiting)	Case 1 Safety Factor (Limiting)	Case 2 Safety Factor (Limiting)
		Based on 2006 data confirmed by 2008 data	100 mil local reduction in Bay 1	50 mil reduction of Bay 19
Refueling	2.0	3.54 Bay 3	3.21 Bay 3	3.46 Bay 3
Post Accident Flooding	1.67 (Service Level C)	2.02 Bay 19	2.01 Bay 19	1.98 Bay 19

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Drywell Description

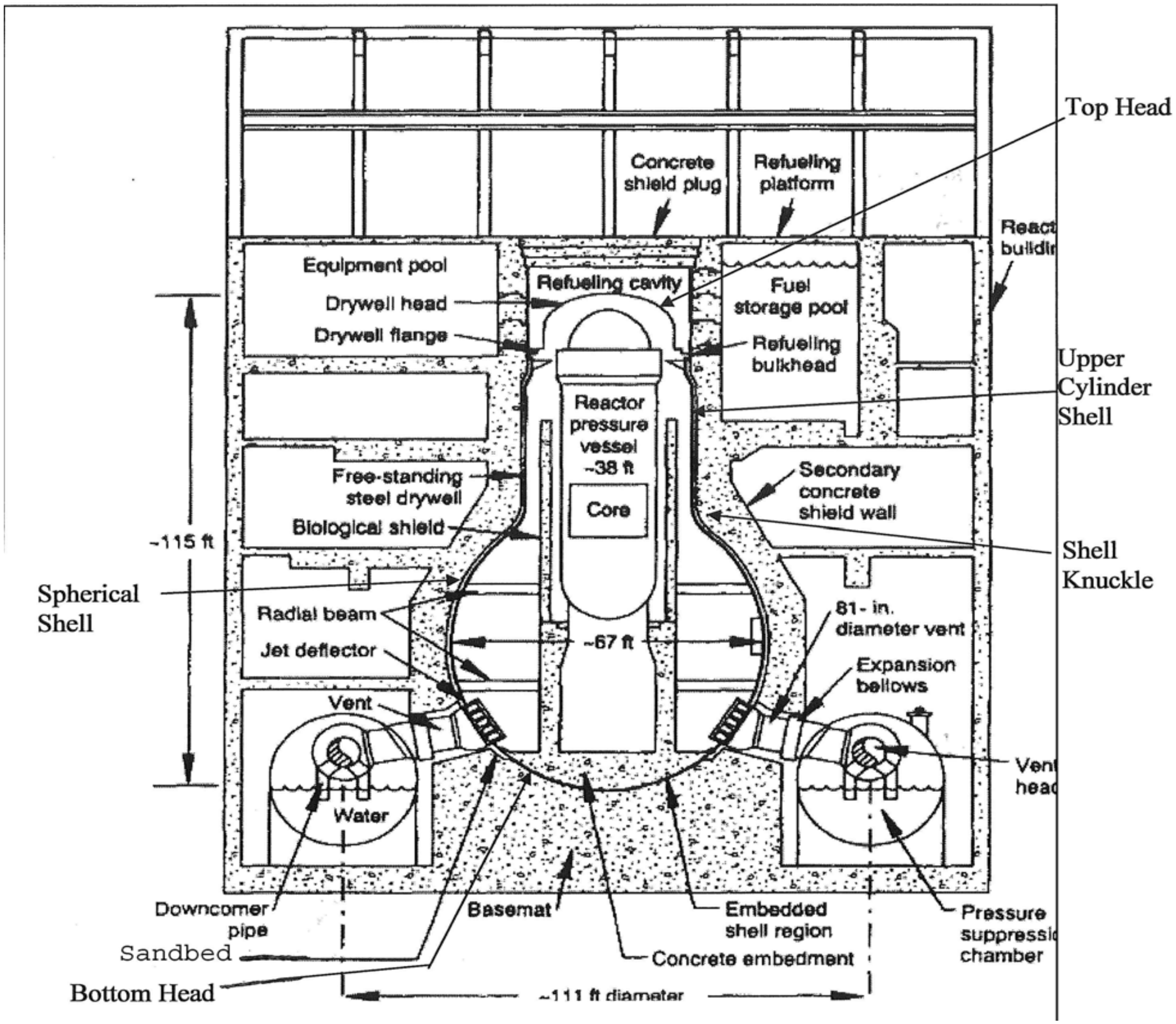

Figure 1-1: Oyster Creek Containment Schematic

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Analysis Summary

- ✓ **Detailed finite element model developed using design drawings**
- ✓ **Shell thicknesses were developed based on UT thickness data**
- ✓ **Current licensing basis inputs such as code of record, loads and load combinations were used**
  - **The Oyster Creek drywell vessel was designed, fabricated and erected in accordance with the 1962 Edition of ASME Code, Section VIII and Code Cases 1270N-5, 1271N-5 and 1272N-5**
  - **For the size of the region of increased membrane stress, guidance sought from the 1989 Edition of ASME Code (including Winter 1991 Addenda), Section III, Subsection NE, Class MC Components**
  - **For the post-accident stress limits, Standard Review Plan Section 3.8.2 was used as guidance**
- ✓ **Buckling analysis performed**
  - **Allowable Stress Values per Section NE-3222 of the 1989 Edition (with Winter 1991 Addenda) of the ASME Code, Section III, Division 1, Subsection NE, Class MC Components**
  - **Modified Capacity Reduction Factor utilized in accordance with Code Case N-284-1 whose primary author was Dr. Clarence Miller**
  - **Code minimum safety factors satisfied**
- ✓ **Stress evaluation performed**
  - **Stresses are within Code allowables**

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Drywell Thickness Description

Sandbed Measurement Locations

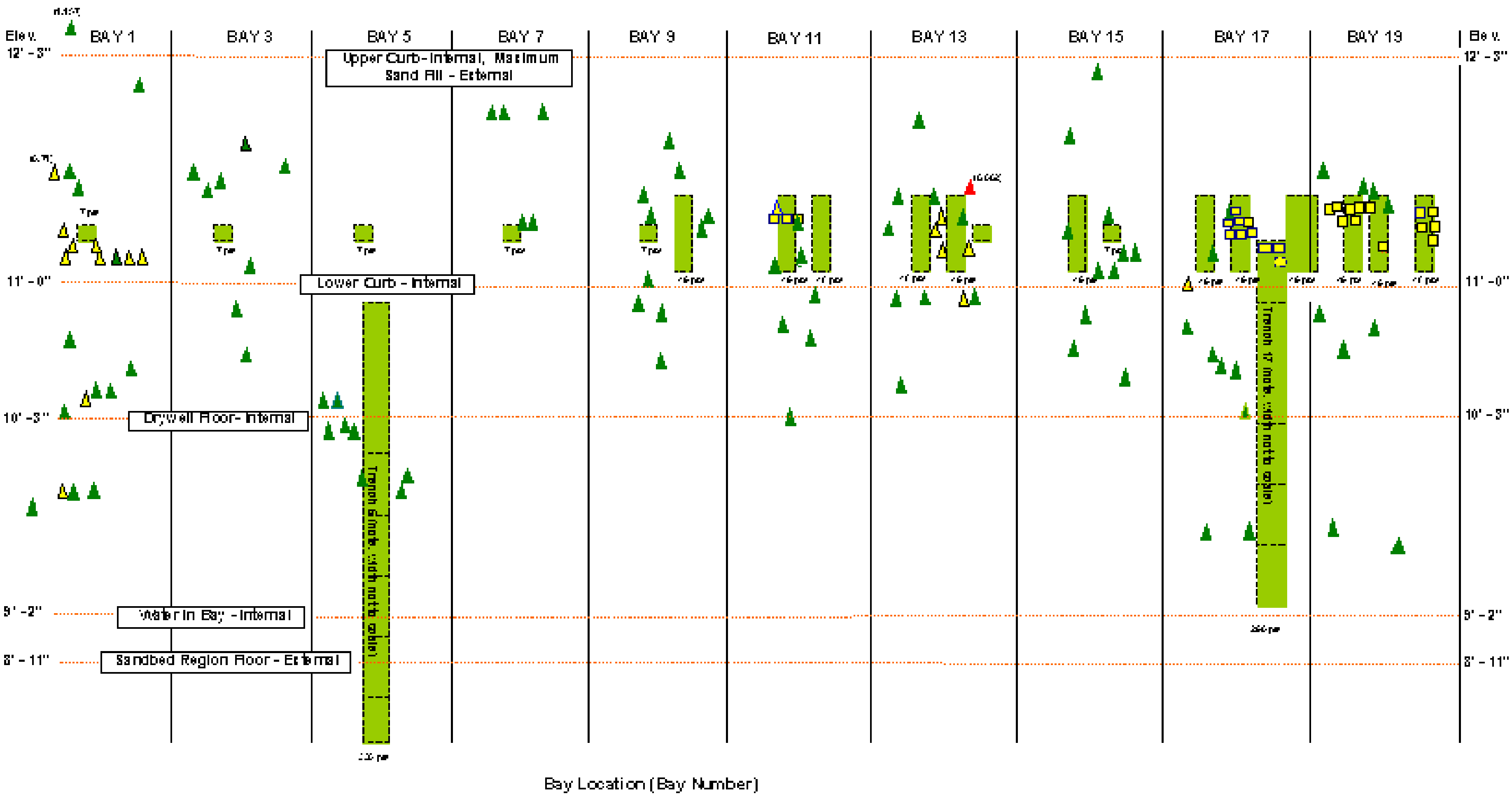
2006 Measurement Locations in the Sandbed Region

Color Code for thickness:

Green = UT Measurements > 736 Mils
Yellow = UT Measurements Between 636 and 736 Mils
Red = UT Measurements Between 536 and 636 Mils

Location / Type of UT Measurement

△ External Point UT Measurements
⊡ Internal Grid UT Measurements
□ Internal Point UT Measurements



Subcommittee Question #1

- ✓ Why is it appropriate to use the UT Internal Grid averages as the modeled thickness for large areas of the sand bed bay?
- ✓ Response:
  - The internal UT grids were located based on a series of data taken to locate the thinnest general areas for ongoing monitoring. Therefore, these grids are representative of the general area average thickness, biased on the thin side.
  - The half buckling wavelength is large, on the order of 5 to 8 feet, which indicates a bay-wide effect. Therefore, the use of average thickness over a bay is acceptable.

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Sandbed Internal UT Measurements

- ✓ From 1983 to 1986, measurements were taken around the inside of the drywell at elev. 11’3”
  - Over 500 initial data points were measured
  - When thin locations were identified, UT measurements were taken horizontally and vertically to locate the thinnest locations
  - UT grid measurements were taken at the thinnest locations
  - 19 locations were selected for ongoing corrosion monitoring with at least one grid is located in each of the 10 bays
- ✓ UT measurements are obtained at these locations every other refueling outage as part of the ongoing aging management program

The UT Internal Grid locations are representative of the general area average thickness, biased on the thin side. Therefore, the UT Internal Grids measurements are appropriate to use as inputs to conservatively model general bay thicknesses.

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Sandbed Trench UT Measurements - Background

✓ Trenches in Bays 5 and 17 were excavated in 1986 to characterize the extent of corrosion in sand bed at elevations below the drywell interior floor

- Bays 5 and 17 were selected because UT measurements indicated these bays had the least and the most corrosion, respectively
- The trenches extend to about the elevation of the bottom of the sand bed
- UT measurements taken in the trenches confirmed that the corrosion below elev. 11’ 3” was bounded by the monitoring at elev. 11’ 3”.

This supports our conclusion that the UT Internal Grid measurements are appropriate to use as inputs to conservatively model general bay thickness.

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Use of Average Thicknesses

- ✓ Local Buckling Stresses depend on the applied stress over the half buckle wavelength L_c
  - $L_c = 3.72(Rt)^{0.5}$
  - For the Oyster Creek Drywell Shell, the half buckle wavelength varies between 62 inches and 89 inches
  - For shells with variable thickness, the thickness can be averaged over a distance of, at least, the half buckle wavelength L_c
- ✓ Tests (Miller, 1982) have been conducted on axially compressed shells with unreinforced openings which show little reduction in the buckling strength when the diameter of the hole, d, is $< 0.8(Rt)^{0.5}$. For the Oyster Creek drywell shell d = 13 in. to 18 in.
  - A hole less than 13 inches will have little effect on the buckling strength, therefore, thinned areas less than 13 in. will have little effect on the buckling strength

Conclusion: Use of average thicknesses for a bay as input to the 3D Analysis is acceptable.

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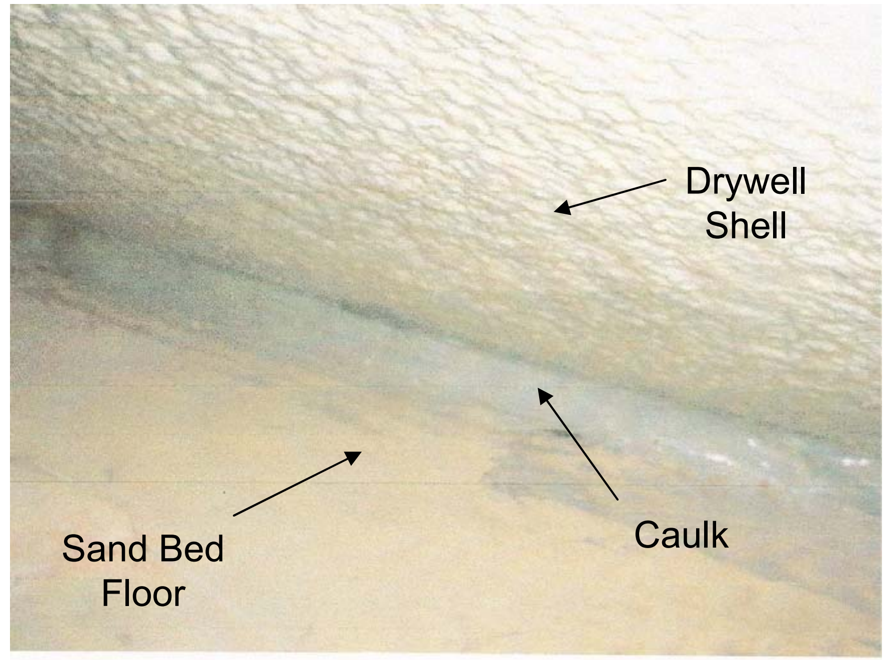
Bay 19 Thickness

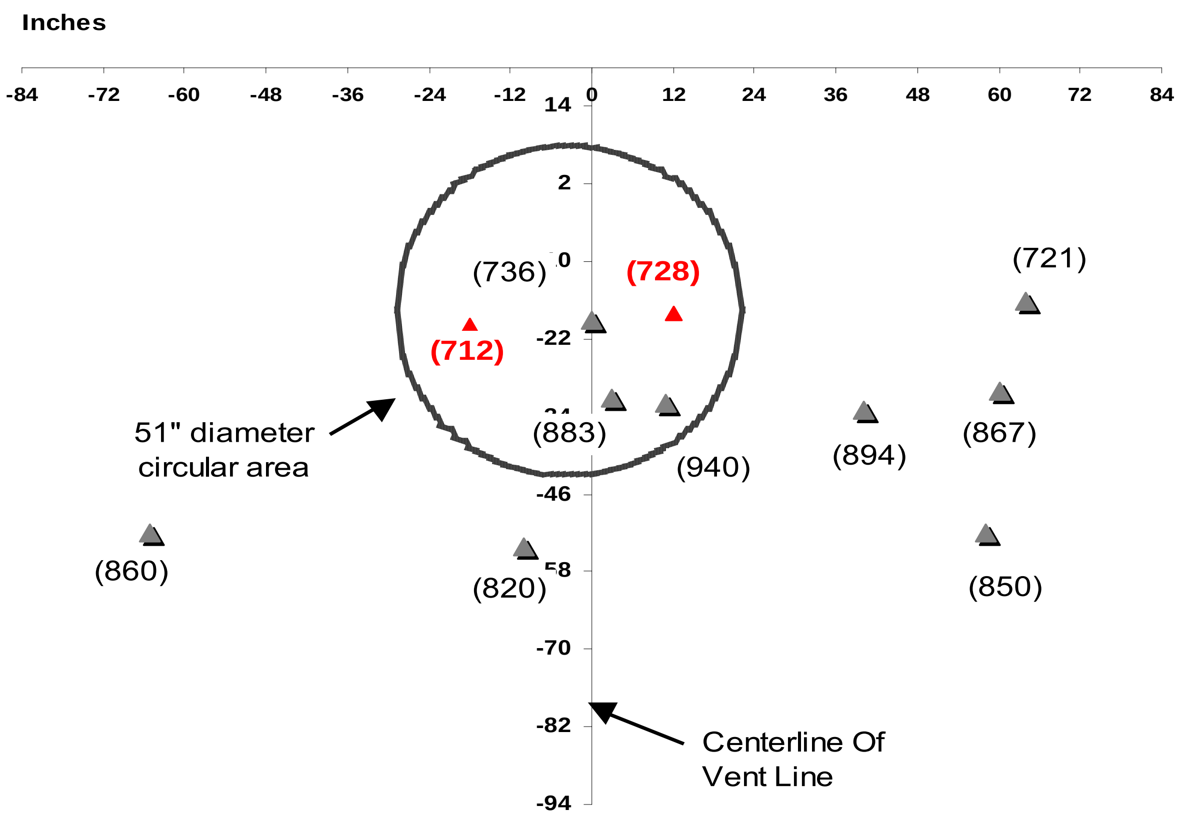
- ✓ The bay exhibits historical corrosion above and below Elevation 11’-0”
- ✓ 3 internal grids (All nominally 49 points) are used to measure shell thicknesses in Bay 19
- ✓ Average of three internal grids used as general area thickness for entire bay (826 mils)



Bay 19 (2006)

Bay 19 Locally Thinned Area

Bay 19 - Location of 2006 External Measurements
Near Modeled Locally Thin Area (Thickness in mils)



Average of Red locations (720) was input to model
Gray locations were not input to model

Reference
C-1302-187-5320-024

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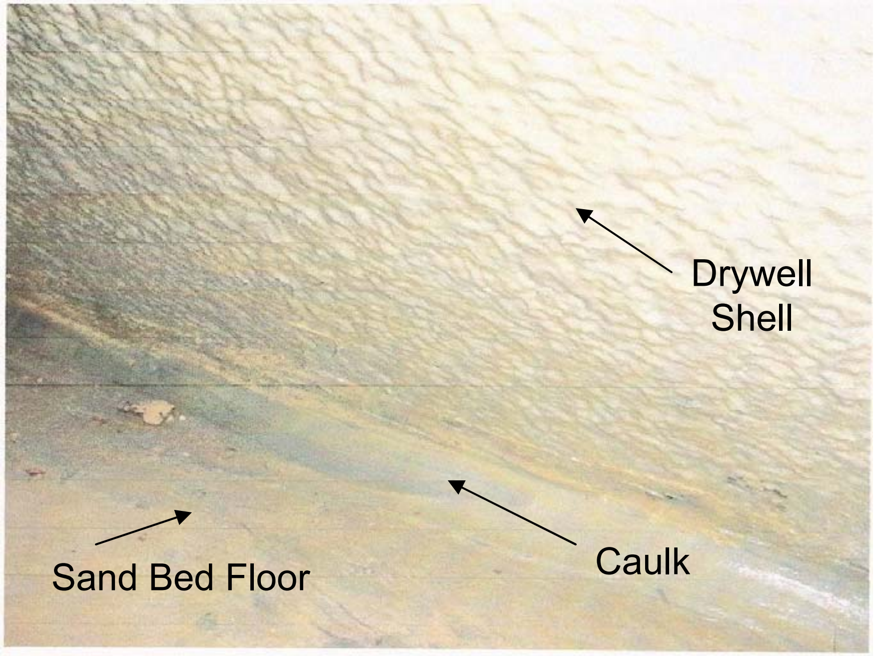
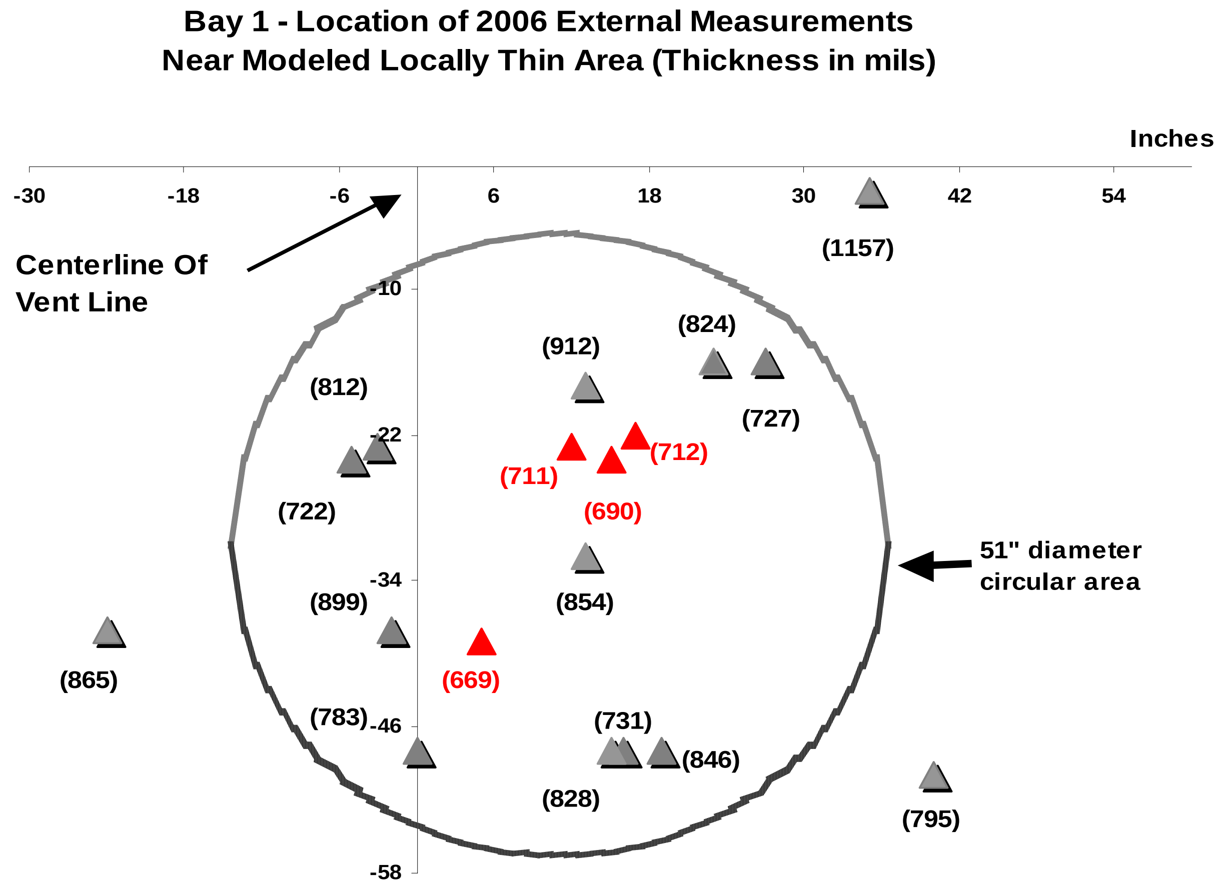
Bay 1 Thickness

- ✓ Visual observation of the external shell surface in Bay 1 indicates the presence of historical corrosion
- ✓ 1 internal grid (7 point) is used to measure shell thickness in Bay 1
- ✓ Internal near nominal grid shell readings for Bay 1 indicate that the grid location is above the former sand/water/air interface boundary
- ✓ Adjacent bay (Bay 19) is one of the most corroded bays
- ✓ Bay 1 thickness was conservatively estimated to be the same as Bay 19 thickness



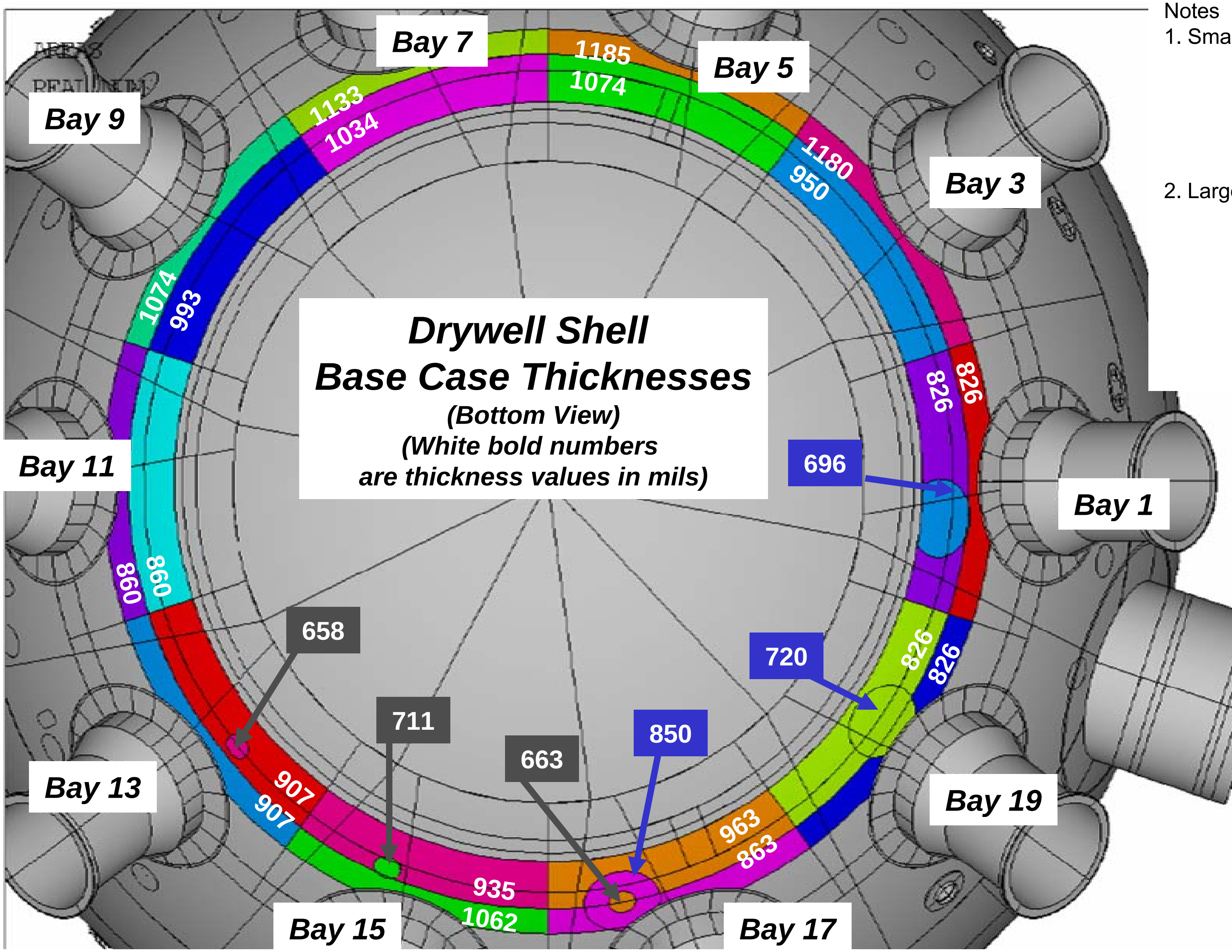
Bay 1
(2006)

Bay 1 Locally Thinned Area



Average of Red locations (696) was input to model
Gray locations were not input to model

Reference
C-1302-187-5320-024



Notes

1. Small-diameter circles in Bays 13, 15, and 17 represent 18-inch diameter locally-thinned areas that were modeled as part of the "base case."
2. Large-diameter circles in Bays 1, 17 and 19 represent 51-inch diameter locally-thinned areas that were modeled as part of the "base case."

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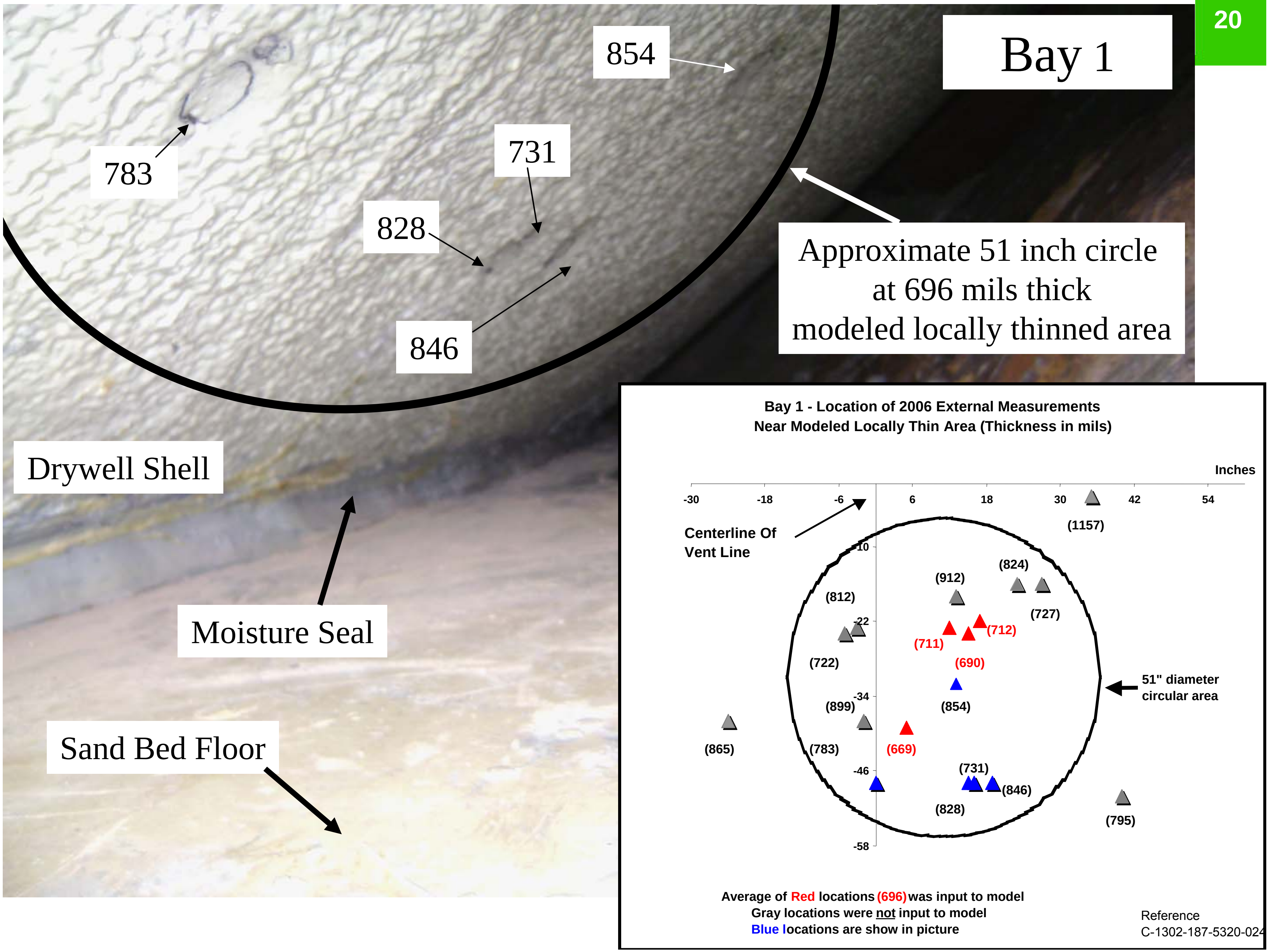
Subcommittee Question #2

- ✓ Why are the External UT points considered biased thin?
- ✓ Response:
  - The External UT Points were identified visually as thin areas for further evaluation. The areas were also ground to permit UT measurement. Therefore, they are biased thin.

Development of External UT Locations

- ✓ After the sand and corrosion byproducts were removed from the sandbed bays, the thinnest locations in each bay were identified.
- ✓ Each bay was visually inspected and the thinnest local spots were investigated both visually and using UT measurements.
- ✓ Approximately 100 locations were identified and mapped.
- ✓ The external surface of the shell was rough, requiring most of the locations to be ground down to create small flat surfaces so the UT probe could be placed perpendicular to the shell wall.
  - This resulted in small 1 to 2 inch diameter dimples in the surface with relatively thinner local areas (biased thin) that were then measured by UT.
  - Micrometer characterization showed that the grinding process may have removed up to 100 mils.
  - Between the individual External UT points, the shell is thicker.

The External UT points are biased thin. They were used to develop the locally thinned modeled areas. It is not appropriate to use these individual measurements to determine general area thicknesses.


Bay 1
854
783
731
828
846
Approximate 51 inch circle
at 696 mils thick
modeled locally thinned area
Drywell Shell
Moisture Seal
Sand Bed Floor
Bay 1 - Location of 2006 External Measurements
Near Modeled Locally Thin Area (Thickness in mils)
Inches
-30
-18
-6
6
18
30
42
54
-10
-22
-34
-46
-58
Centerline Of
Vent Line
(1157)
(824)
(912)
(812)
(727)
(712)
(711)
(722)
(690)
51" diameter
circular area
(899)
(854)
(865)
(783)
(669)
(731)
(846)
(828)
(795)
Average of Red locations (696) was input to model
Gray locations were not input to model
Blue locations are show in picture
Reference
C-1302-187-5320-024

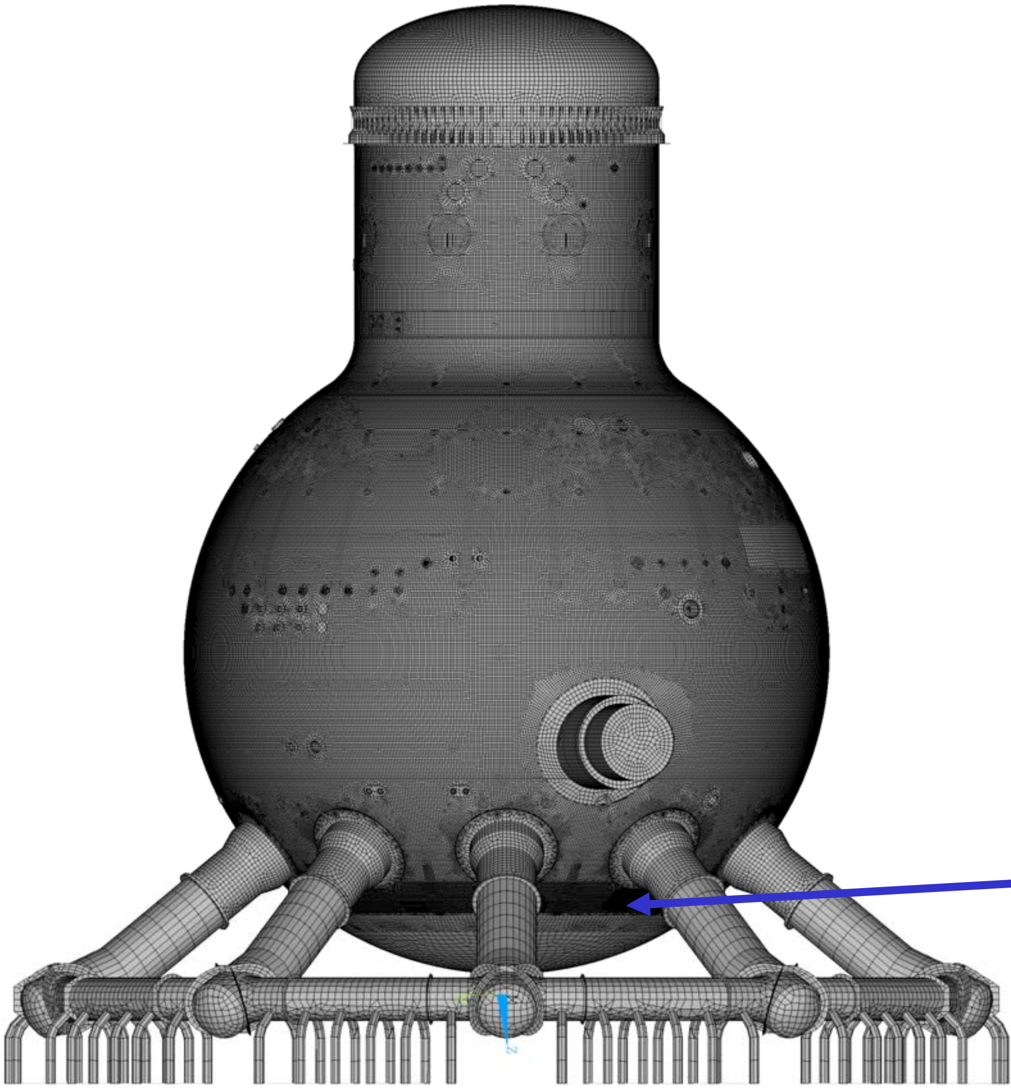
Finite Element Model

Finite Element Model

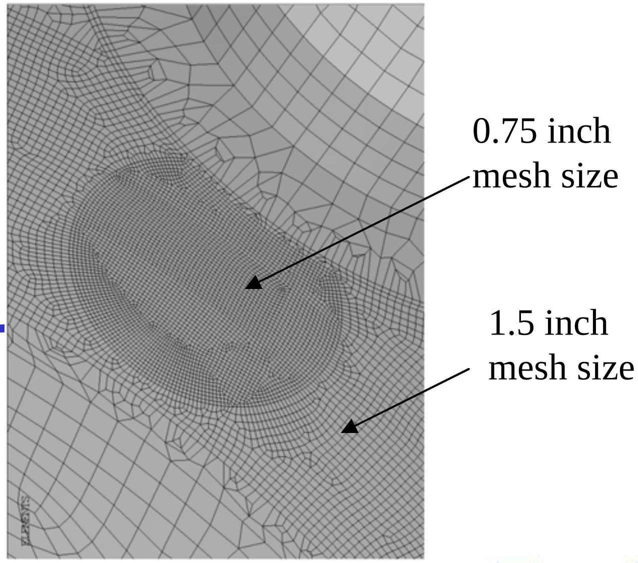
- ✓ ANSYS
  - Release 8.1 and ANSYS Release 11 used to generate the three dimensional model
  - Industry accepted, finite element analysis software
- ✓ Dimensions and material properties obtained from OEM drawings
- ✓ Model Size
  - Approximately 406,000 elements
  - Approximately 400,000 nodes
- ✓ Mesh Sensitivity
  - Up to approximately 1,000,000 elements

Finite Element Mesh

MESH SIZES	
Region	**General Mesh Size (Inch)**
Local Thinning Area	0.75
Sandbed Region	1.50
Mid Spherical Shell	3.00
Knuckle Region	3.00
Cylindrical Shell	3.00
Top Dome	6.00
6 inch or smaller penetrations	2.50
8 inch or larger penetrations	5.00
Vent Pipes	6.00
Vent Header	10.00
Equipment Hatch	6.00
Bottom Spherical Shell (within concrete)	12.00



Elevation View of Finite Element Model



Locally Thinned Area in Bay 19

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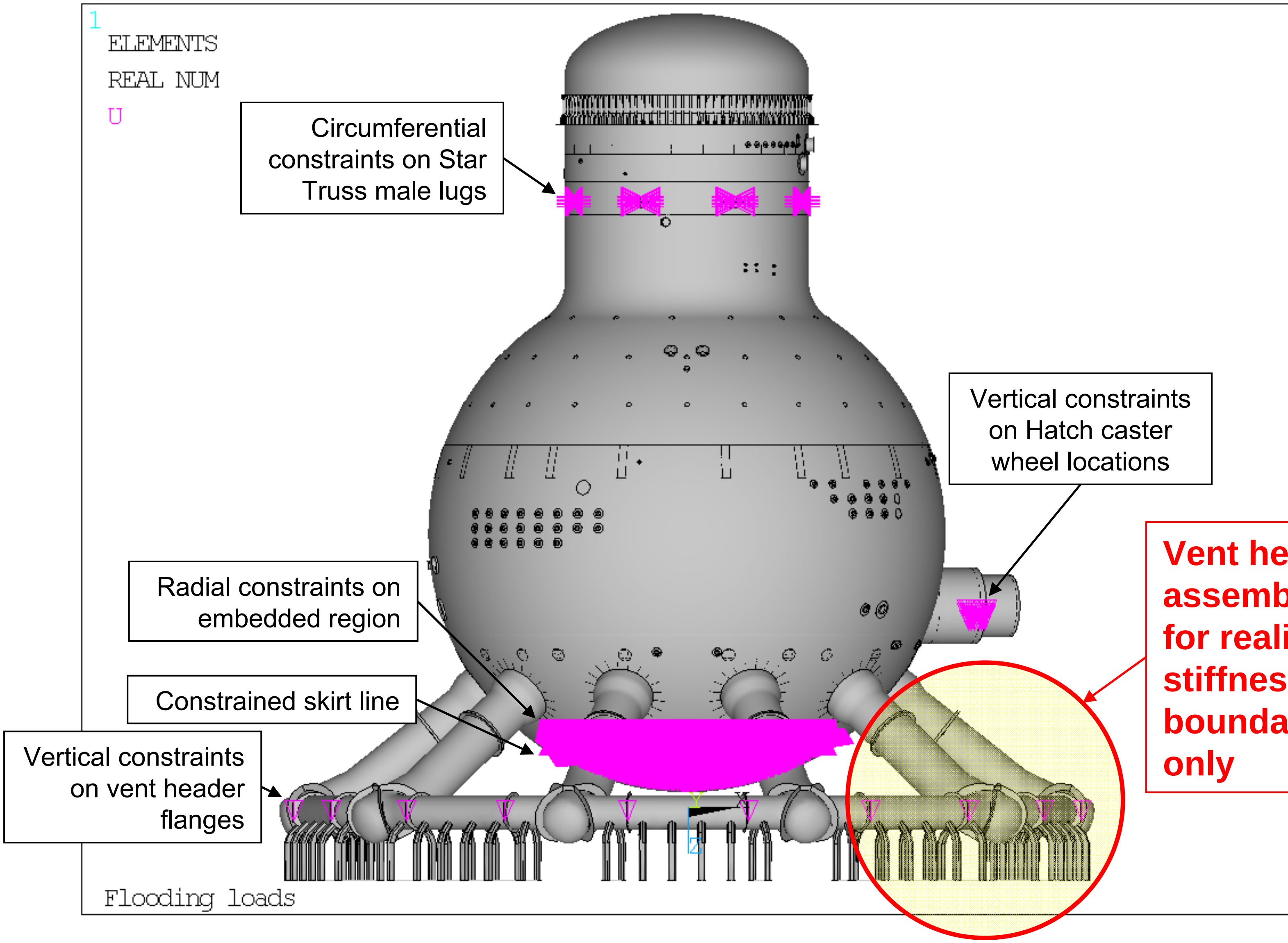
Subcommittee Question #3

- ✓ Describe specifically the modeling of the vent header boundary condition. Is this boundary condition appropriate as to the effect on the shell? Will the downcomer vents buckle?
- ✓ Response:
  - The vent header boundary condition modeling is appropriate and the boundary condition does not provided added benefit to the shell analysis
  - The vent pipes/header will not buckle before the shell

Boundary Conditions & Vent Header Interaction



Vent header assembly included for realistic stiffness/interaction boundary conditions only

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Drywell Stiffness Interface with Vent Header

- ✓ Detailed modeling of the vent headers/downcomers is included for realistic representation of stiffness/interaction of components attached to the drywell shell
  - Similar to the use of stiffness matrix as boundary conditions
- ✓ Detailed modeling reduces conservatism in stress/buckling results
  - Account for realistic load transfer
  - Alternate simplified approach is to model with estimated boundary conditions at vent pipes/vent header interface location

Reaction Loads at Embedded Sandbed Region

- ✓ Loads going through the vent pipes are low

- ✓ Case: Flooding Loads

  - 93% of reaction force was at the embedded bottom head boundary conditions

  - 4% of reaction force was at the vent header boundary conditions

  - 3% went to other boundary conditions (equipment hatch and star truss)

Vent Pipes will not Buckle before the Shell

- ✓ R/t: Vent pipe ≈ 150, Vent header ≈110, Downcomers ≈ 48
  - Cylindrical shell R/t ≈ 300
  - Spherical shell R/t ≈ 400 to 600
- ✓ Length between stiffeners: Vent Pipe ≈ 85”, Vent header ≈ 48”, Downcomers ≈ 75”
  - Cylindrical shell length between stiffeners = 103”
  - Spherical shell length between stiffeners = 235” to 332”
- ✓ In Code Case N-284-1, for cylinder, a smaller R/t gives a larger capacity reduction factor and higher buckling strength

Conclusion: Based on the comparison of R/t and the length between stiffeners for the vent pipes and the shell, the vent pipes would have higher buckling strength and larger safety factors than the shell.

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Sensitivity Studies

Sensitivity Studies

- ✓ Case 1: Reduce the wall thickness of the 51 inch defined locally thin area in Bay 1 by 100 mils (from 696 mils to 596 mils), keeping the general area of the thickness in Bay 1 constant (826 mils)
- ✓ Case 2: Reduce the wall thickness of the general area in Bay 19 by 50 mils (from 826 mils to 776 mils), keeping the locally thin area constant (720 mils)

Results (Sandbed Region)

Load Combination Case	Required Safety Factor	Base Case Safety Factor (Limiting)	Case 1 Safety Factor (Limiting)	Case 2 Safety Factor (Limiting)
		Based on 2006 data confirmed by 2008 data	100 mil local reduction in Bay 1	50 mil reduction of Bay 19
Refueling	2.0	3.54 Bay 3	3.21 Bay 3	3.46 Bay 3
Post Accident Flooding	1.67 (Service Level C)	2.02 Bay 19	2.01 Bay 19	1.98 Bay 19

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Subcommittee Question #4

- ✓ How is the selection of the 100 mil local reduction and 50 mil bay-wide reduction related to UT data?
- ✓ Response:
  - **Local Area Reduction**: The measurement difference between individual external UT points was -6/+1 mils. The 100 mil local reduction is over 15 times the observed external UT measurement difference and, therefore, is expected to bound data uncertainties.
  - **General Bay-Wide Reduction**: The internal UT Grid measurement standard errors range from +/- 2 to +/- 16.6 mils. The 50 mil bay-wide reduction is at least 3 times the standard error for the data used to determine the general bay-wide thickness input and, therefore, is expected to bound data uncertainties.
  - UT measurements demonstrate that the drywell shell is not experiencing corrosion; however, a hypothetical corrosion rate of 2 mils per year would yield a postulated bounding value of 8 mils over a 4 year measurement interval. The selected reductions of 100 mil local or 50 mil bay-wide are much greater.

Overall Results/Conclusions

Overall Results/Conclusions

- ✓ For normal operating conditions, the limiting condition is the refueling condition. For this condition, the current safety factor of the limiting sandbed bay is 3.54, which results in a safety margin greater than the ASME Code specified safety factor of 2.0.
- ✓ For emergency conditions, the limiting condition is the post-accident flooding condition. For this condition, the current safety factor of the limiting sandbed bay is 2.02, which results in a safety margin greater than the ASME Code specified safety factor for Service Level C conditions of 1.67.
- ✓ Sensitivity studies demonstrate that significant thickness changes could occur in the future, or measurement uncertainties could exist, without a significant reduction in margin to ASME Code specified safety factors.

Questions?

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NRC Staff Review of Oyster Creek Drywell Shell 3-D Finite Element Analysis

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Region I

Advisory Committee on Reactor Safeguards
October 8, 2009

TOPICS

- Overall Perspective
- Historical Perspective of Analyses
- NRC Inspections
- NRC Staff Review
- NRC Conclusions

OVERALL PERSPECTIVE

- Corrosion identified late 1980s
  - Narrow band of the lower spherical portion of the shell – “sandbed” region
  - Prevalent in half of bays

- Remediation
  - Removed source of corrosion (wet sand)
  - Protected with a robust coating
  - Ultrasonic test measurements indicate corrosion arrested; upper shell measurements indicate low general corrosion

OYSTER CREEK DRYWELL SHELL ANALYSES

- General Electric Analysis - 1992
  - Assumed uniform reduction in shell thickness (sandbed region) to minimum measurement (0.736 in.) and locally thinned area (0.536 in.)
  - Modified capacity reduction factor – refuel load
  - Current licensing basis analysis

- Sandia - 2007
  - Conservatively modeled degradation based on average of external UT measurements, locally thinned area set to bay lowest thickness
  - Conservative assumptions based on no access to proprietary design data
  - Unmodified capacity reduction factor – refuel load

- Structural Integrity Associates – 2009
  - Realistic analysis to compute margins in existing drywell shell above ASME Code
  - Performed base case analysis and sensitivity analyses to address measurement uncertainty
  - Access to GE proprietary design data
  - Modified capacity reduction factor – refuel load

All analyses demonstrate margins that exceed ASME Code

INDEPENDENT REVIEWS

- Brookhaven National Laboratory review of GE analysis for NRC
- ACRS review of Sandia analysis as a part of license renewal review
- Becht Nuclear Services review of SIA analysis for State of New Jersey

All three reviews point to the conclusion that the Oyster Creek drywell shell can perform its intended function without compromising the ASME Code margins

NRC STAFF REVIEWS

- January 22, 2009, submittal
  - Base case and sensitivity cases
  - Detailed rigorous review of submittal
  - Part of license renewal inspection
    - Inspection report issued (ML091380379)
  - Staff assessment issued (ML091310413)

- September 9, 2009, submittal
  - Two revised modeling approximations
  - Detailed review of submittal
  - Performed audit to supplement review
  - Audit report to be issued

NRC INSPECTIONS

ACTIVITIES

- Region I inspectors observed Exelon’s drywell shell inspections in 2006 and 2008
- Verified by observation that external measurement points were chosen in worst corrosion locations

OBSERVATIONS

- Drywell exterior coating was, in general, in good condition
- UT inspections were conducted and reported in a competent, accurate manner
- Sandbed general conditions were good, some minor repairs to seals and coating were needed

NRC REVIEW FINDINGS

CONSERVATIVE ASSUMPTIONS

- Bounding seismic response spectra
- In post accident flooding case, all the water in included as added mass in the drywell seismic analysis
- Conservative 2% damping under OBE
- Post accident Flooding Case evaluated against ASME Service Level C limits
- Support provided at locations of Star Truss/bioshield wall conservatively neglected from the analyses, especially in buckling evaluation
- Sizes of locally thinned areas in sandbed region conservatively mapped

NRC REVIEW FINDINGS

FINITE ELEMENT MODEL

- Realistic estimate analysis of current condition of the drywell shell including realistic simulation of locally-thinned areas identified in 1992 and confirmed in 1994, 2006 & 2008
- Extensive model with general element size of 3”, refined to 0.75” in locally-thinned areas

STRESS EVALUATION

- Refueling case limiting load combination in Levels A and B service conditions, while post-accident flooding case limiting for Level C service condition

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NRC REVIEW FINDINGS

BUCKLING EVALUATION

- Where applicable, CRF modified to account for benefit of hoop tensile stresses in the shell as a result of the weight of the water in the reactor cavity pool
- Refueling and post-accident flooding load cases are controlling for buckling evaluation
- In refueling load case, minimum FS 3.39 in the cylindrical region compared against a min FS of 2.0
- In flooding load case, minimum FS 2.0 in the sandbed region, compared against a min FS of 1.67

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NRC REVIEW FINDINGS

SENSITIVITY ANALYSIS CASES

- Two sensitivity analysis cases considered to capture potential uncertainties in location and degradation of locally thinned areas
- Stresses in regions above the sandbed area marginally affected and remain essentially the same as in the baseline analysis … less than 8% increase in stress intensities well below allowable ASME Code limits

NRC CONCLUSIONS

- Overall, the 3-D FEA analysis performed utilizing widely accepted engineering practices consistent with ASME Code, good engineering judgment, and applied conservatively biased realistic assumptions
- All components of the drywell shell show adequate margins against instability under refueling loads and post-accident flooding loads
- In all loading cases, stresses are less than allowable ASME Code limits
- For refueling load case, margin against buckling is the lowest in the cylindrical shell region, an area that has experienced little corrosion
- Evaluations in all cases (baseline and sensitivity cases) confirm the Oyster Creek drywell shell complies with the ASME Code limits, and provide reasonable and realistic quantification of the available safety margin of the drywell shell for the postulated loading conditions